A Report on the Health of British Columbians

Provincial Health Officer's Annual Report 2000

Drinking Water Quality in British Columbia: The Public Health Perspective

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BRITISH
COLUMBIA

Ministry of Health Planning
Office of the
Provincial Health Officer

October 2001

Ministry of Health Planning
Victoria, B.C.

October 12, 2001

The Honourable Sindi Hawkins
Minister of Health Planning

Madam:

I have the honour of submitting the Provincial Health Officer's Annual Report for 2000.

P.R.W. (Perry) Kendall
MBBS, MSc, FRCPC
Provincial Health Officer

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Highlights

For many years, British Columbia has had the highest reported rate of intestinal illness of all the provinces in Canada, and consuming contaminated water or food has caused most of these illnesses. Since 1980, there have been 29 confirmed waterborne disease outbreaks in B.C. caused by such micro-organisms as *Giardia*, *Cryptosporidium*, *Toxoplasma*, and *Campylobacter*. Many of the outbreaks were the result of water system failures or the absence of adequate treatment. Tens of thousands of British Columbians have been affected during these known outbreaks. A recent study in Greater Vancouver found that drinking water may be contributing to significant levels of day-to-day gastrointestinal illness, although we do not yet have a way to track these statistics precisely.

British Columbia has a system of safeguards to protect the water we drink, including pollution prevention programs for drinking water sources and public health standards for water treatment. The Safe Drinking Water Regulation enacted in 1992 requires water suppliers to monitor water quality and to warn health authorities of potentially unsafe conditions. The *Drinking Water Protection Act*, which received Royal Assent on April 11 2001, provides a framework from which new protective requirements and enforcement measures could be developed by regulation. Even with vast improvements over the years to the regulation and management of water systems, water-related illnesses and outbreaks continue to occur.

The Provincial Health Officer, government ministries, regional health officials, and the B.C. Centre for Disease Control have all been reviewing the measures that need to be in place to prevent outbreaks of waterborne bacterial and parasitic disease and to manage emerging health risks in our water. Following the 1999 Auditor General's Report, *Protecting Drinking Water Sources*, the provincial government asked the Provincial Health Officer to write a report examining the full spectrum of drinking water issues from source to tap.

This year's annual report discusses current drinking water quality issues in British Columbia from a public health perspective. It outlines the regulation and management of B.C.'s water systems and discusses how existing Canadian and international water quality guidelines and scientific evidence guide the public health decisions concerning the safety of drinking water. The health risks of specific microbiological and chemical agents—such as bacteria, viruses, parasites, arsenic, lead and nitrates—that can contaminate drinking water are discussed, as well as the current evidence about how to help prevent those agents from entering or remaining in the water supply. This report also examines the steps necessary to reduce waterborne disease at each component of the water system, from source protection, to water treatment, to maintenance of the pipe infrastructure and distribution system, to the consumer's tap.

There is no way ever to ensure "zero risk" in drinking water. Contamination can occur before testing reveals its presence. But British Columbia can have control systems in place that adequately anticipate and attempt to minimize the risk to consumers. We can do this by ensuring source protection and by providing adequate treatment methods to neutralize or remove any contaminants that may enter the water supply. We can have regular and systematic surveillance, so that if contamination occurs, prompt and aggressive action removes the threat and also effectively and honestly alerts the public to prevent widespread infection or other ill-effects. And we can ensure the proper training and certification of all those involved with delivering drinking water to British Columbians.

Eight Key Messages

Underpinning this report's recommendations are eight key messages related to improving drinking water quality. They reflect the expertise of the Provincial Health Officer, as well as the best evidence from research and the extensive consultations involved in the development of this report.

1. All surface water (water from lakes, creeks, and rivers) is likely to be contaminated. Even the most remote and seemingly untouched water source can be carrying contaminants that may harm human health.
2. The best assurance of safe drinking water at the consumer's tap is a multi-barrier approach. There are four basic barriers that must be in place to ensure that water is safe to drink:
   - At the source – protection of source water quality by limiting or prohibiting wastewater discharges and other sources of water pollution
   - Treatment – adequate treatment such as disinfection and/or filtration
   - During storage and distribution – safeguarding water quality during storage and distribution, and
   - At the consumers tap – monitoring of the distribution system and enforcement of standards.

   A practical tool to assess and manage these multi-barriers is the use of the Hazard Analysis and Critical Control Points (HACCP) approach. While HACCP is most often applied to food safety, it is a system of risk assessment and management that can be adapted to drinking water safety. It focuses on identifying and addressing the junctures in the system (critical control points) where there may be a hazard and the loss of control that could result in an unacceptable safety risk.

3. Management of the water system should be based on assessment and management of public health risk from source to tap, as well as on end product testing. A good test result may lull people into thinking there is no risk to the system. In fact, random monitoring of water quality by microbiological or chemical testing cannot in itself ensure water safety and cannot substitute for good risk assessment and risk management. We must anticipate the risks to our drinking water and take steps to prevent them from occurring, rather than hope we catch them in random tests. Good water system management requires a culture of continuous quality improvement.

4. Better protection and management of the land that surrounds the water source will protect and improve the quality of water at the tap. However, there are limits to what such measures can achieve. Pathogens such as *Cryptosporidium* and *Giardia* are inevitably present in B.C. watersheds. It will always be difficult to maintain low turbidity (cloudiness), particularly during times of high rainfall or during the spring snowmelt. Consequently, appropriate water treatment or alternate water supplies must be in place to handle episodes of poorer source water quality.

5. To prevent disease, all surface water requires disinfection. This generally includes the presence of a detectable disinfection residual at the end of the distribution system. Groundwater systems that are subject to microbiological contamination from surface water should also have disinfection. There are some groundwater systems that after careful assessment and testing may be determined to be safe and to not need disinfection.

6. Maintaining safe drinking water will require investments in filtration and other advanced forms of water treatment. Chlorine and other disinfectants kill many of the micro-organisms that cause disease. Unfortunately, these traditional methods of water treatment do not always neutralize hardy parasites such as *Giardia* and *Cryptosporidium*. Additional purification methods are available, and many water suppliers have already enhanced their treatment systems using these newer technologies. The adoption of treatment standards for all B.C. water systems, with a timeline for compliance, will move B.C. along in this direction.

7. Good, accurate information is essential to any decision-making and management. When it comes to B.C.'s water systems, we currently rely on a patchwork of information about disease outbreaks, boil-water advisories, and statistics collected by individual water suppliers and regulatory staff. British Columbia needs a database that reports on the characteristics of all water systems, water system performance, and the occurrence of water-related illnesses.

8. If we want to improve drinking water quality in British Columbia, we will have to find ways to pay for it. Risk assessments and evaluations, improved treatment plants, more manpower for assessment and monitoring—all of these require adequate funding. There are many ways to raise the capital and operating costs needed for improvements and enhancements—taxation, user-pay, or public-private partnerships are examples. Consumers and politicians will need to be aware of the benefits and costs of drinking water improvements, in order to make the best decisions about how water systems

should be managed and where the money will come from. Nevertheless, it must be stated that without adequate funding, no improvements can take place.

Blueprint for Action

Chapter 6 of the report contains 32 specific recommendations to help improve water quality in British Columbia. With each recommendation, we have identified the agency or individual that should take the lead in putting the recommendation into action. Together, the recommendations form a blueprint that can be used to focus our efforts on the most urgent and correctable problems that will have the greatest returns in terms of improved public health. If the recommendations are implemented, we can expect to see continued improvement in drinking water quality and a reduction in water-related illness in British Columbia.

[illegible]

Blueprint category	Recommended actions
1 Commitment to drinking water quality	1. Legislated authority*
	2. Size of regulated systems*
	3. New and orphaned water systems
	4. Groundwater
	5. Cross-connection control
	6. Inter-ministry coordination*
	7. Drinking water specialists
	8. First Nations water systems
	9. Standards and guidelines
	10. Microbiological treatment standards*
	11. Fluoridation
	12. Additional resourcing
	13. Access to capital funds
2 Risk assessment and information gathering	14. Multiple barriers and critical control points
	15. Hazard identification and risk assessment
	16. Surveillance for waterborne disease
	17. Standardized data-set and provincial database for drinking water quality
3 Planning for risk management	18. Risk management plans
	19. Triggering of boil-water advisories
	20. Regional action plans
4 Quality assurance and good management practice	21. Laboratory accreditation
	22. Testing of raw water sources
	23. Terms and conditions of operating permits
	24. Operator training and certification
	25. Practice guidelines—local health officials
5 Public involvement and education	26. Community involvement
	27. Public education
6 Accountability	28. Performance measures*
	29. Public reporting*
7 Research and evaluation	30. Watershed and groundwater research
	31. Walkerton inquiry report
	32. Long-term evaluation of results

* Priority recommendations

Priority recommendations

Each of the 32 recommended actions is important and will contribute to improving the safety of British Columbia's drinking water. To get the maximum benefit from existing drinking water programs and to prepare for the future, the most urgent areas for action are:

Provide legislative authority that establishes drinking water as the priority water use (Recommendation 1)

Many of the watersheds in the province serve a variety of uses—forestry, mining, agriculture, urban development, and recreation—as well as being a source for drinking water. They require management so that drinking water systems that may be vulnerable to microbiological, physical and chemical contamination are sufficiently protected while allowing for appropriate multiple uses.

> **Recommendation 1 –** Ensure that there is legislative authority (such as the *Drinking Water Protection Act*) that gives priority to the safety of drinking water and that covers management of the system from source to tap. **Lead: Ministry of Health Services.**

Consider establishing various levels of regulation, depending on the size of the water system and the population served (Recommendation 2)

British Columbia has three times as many water systems as it did ten years ago. Most of the increase has been among small water systems serving two to 14 connections each. It has been suggested that the threshold of regulation be increased to five, 10 or even 25 connections. While it is true that if British Columbia's 2,000 small systems were de-regulated public health resources would be freed up to focus on large systems, all British Columbians deserve protection from waterborne illness. A workable alternative is to establish different levels of drinking water standards according to the type and size of the water system.

> **Recommendation 2 –** (a) Continue to apply drinking water legislation and regulations to all systems with one connection or more that serve more than a single-family dwelling. (b) Study and carry out public consultation on the feasibility of taking an accreditation or graded approach to small water systems (with less than 15 connections), rather than full compliance with legislation. (c) If legislation is amended such that small water systems are subject to less stringent regulatory requirements, provide training for water system owners, so they know how to protect users by ensuring safe drinking water. (d) Provide public awareness and education regarding any changes, as well as some means of informing homeowners of their responsibilities and liabilities.
> **Lead: Ministry of Health Services.**

Make a commitment to coordination in the regulation and management of water systems (Recommendation 6)

The duties and responsibilities for water quality in the province are split between a number of ministries and agencies (see Table 2). Clear government accountability, increased cooperation, and coordination are needed.

> **Recommendation 6** – Establish—either through legislation or administrative policy—a lead ministry coordination function, or other coordinating mechanism for water quality issues.
> **Lead: Provincial government.**

Require microbiological treatment standards (Recommendation 10)

Water treatment is the most effective means of protecting the public from water-related illness. Compared to many other jurisdictions, B.C. has a long history of under-treating its drinking water. Setting and implementing treatment standards (such as required log reductions for each system) would minimize the health risks that British Columbians face from waterborne contaminants.

> **Recommendation 10** – a) Incorporate treatment standards into the operating permits for water systems. b) Set a minimum level of treatment (required log reductions for pathogens found in B.C. waters, particularly *Giardia* and *Cryptosporidium*) to be met by all water treatment systems. c) Develop a consistent set of guidelines for use by medical health officers in deciding when, where, and how much additional treatment may be required for a particular system.
> **Lead: Ministry of Health Services and local health officials.**

Establish a standard set of performance measures, along with methods for public reporting of results (Recommendations 28 and 29)

The number of waterborne disease outbreaks, contacts with the health care system for intestinal diseases, and an annual count of boil-water advisories are some of the performance measures we have available. These measures are useful, but they have limitations in terms of completeness and timeliness. We do not at present know, for example, how many systems treat their surface water, and how many simply deliver untreated water to consumers. How many log reductions does each system achieve in its treatment against *Giardia* and *Cryptosporidium*? How many systems have personnel who have undergone operator-training certification? These are some of the important data elements we should know. An expanded, standard set of measures —and methods to collect the needed information—would assist in gauging our success in protecting the quality of drinking water. The proposed data-set (Appendix E) provides the required data elements for several potential performance measures.

> **Recommendation 28** – From a standardized data-set and the recommended provincial database for drinking water quality (see recommendation 17), establish a smaller set of key measures to be used for reporting on the quality of British Columbia's drinking water and the performance of drinking water systems.
> **Lead: Ministry of Health Services, Ministry of Water, Land and Air Protection, and Ministry of Sustainable Resource Management.**

The public has the right to know the results of monitoring their water supply. Dissemination of this information, a requirement for true public accountability for water management, has become the common practice in other jurisdictions. It is already being made available by some of the larger suppliers and health regions in B.C. (See: Capital Region, Greater Vancouver and Fraser Valley web sites—Appendix B). Regulations currently require public notification of test results on the regulated microbiological contaminants and of other monitoring results. Some do this, however, only on a specific request by a member of the general public, if for example a citizen happens to call and ask for the results. Publicly available reports produced from this information would improve accountability.

> **Recommendation 29** – (a) Provide the public regularly with results of chemical, physical, and microbiological monitoring of their drinking water supply and with an interpretation of the health significance of these results, with the assistance of the medical health officer. **Lead: Water suppliers.** (b) Make regional information on water quality and water systems (see recommendation 28) available to both professionals and interested members of the public, including information on what to do during boil-water advisories. **Lead: Local health authorities.**

Introduction

Most of the time, British Columbia's drinking water at the tap is safe to drink. Thus, many of us take safe drinking water for granted. This report explores drinking water issues—from the water's source to the consumer's tap. Waterborne illness has been and continues to be a serious public health concern in British Columbia, affecting the health of the population and the economy.

Drinking Water Quality—A Public Health Issue

Water is essential for human health and survival. Each of us needs to replace in lost fluids the equivalent of between one and two litres of water a day. Deprived of all food, we can last for more than a month. Without water, we cannot survive more than a week (Health Canada, *Water—facts and tips*).

British Columbia is seemingly blessed with an abundant supply of fresh water. Our landscape abounds with glacier-fed streams, raging rivers, and mountain lakes—water sources that appear to be pure and inexhaustible. Vast areas of the province receive regular and plentiful rainfall. Compared to many other regions in North America and the world, it would seem we have few worries about the quantity or quality of our drinking water. Indeed, for years we have been so confident about the supposedly pristine nature of our water supply that a number of our water systems simply deliver water from the source to the tap with little or no treatment.

The term "public health" refers to a system of programs, services, and approaches aimed at improving the health of the population.

Protecting Canadians against health and safety risks is an essential public health function. Science (providing evidence), surveillance (monitoring and forecasting health trends), risk management (assessing and responding to risks), and intervention (taking action) form the basis of health protection activities.[1]

Many health protection activities, including those related to drinking water safety, are considered so important to the health of the public that they are enshrined in legislation.

[1] *Survey of Public Health Capacity in Canada: Highlights—Final Draft.* Federal, Provincial and Territorial Advisory Committee on Population Health, March 2001.

A series of recent issues, including an outbreak of waterborne illness that infected an estimated 2,700 people and killed seven in Walkerton, Ontario, have brought into sharp focus the danger of taking drinking water quality for granted. Across Canada and North America, the public and governments are looking with fresh eyes at the potential risks to human health by the contamination of our water systems and are examining ways to reduce or remedy those risks.

Water quality can be difficult to define. Water may be acceptable for some purposes but not for others. Water that provides a suitable habitat for fish or other aquatic life may not be fit for humans to drink and vice versa.

This report discusses current drinking water quality issues in British Columbia from a public health perspective. Its aim is to provide an in-depth exploration of water quality issues from the water's source to the consumer's tap in relation to the health of the B.C. population. Widespread consultation was carried out to ensure that the information presented here is accurate and that it incorporates ideas from the many people involved.

The report outlines the role of the public health system, other government ministries, the water suppliers and the consumers in the regulation and management of B.C.'s water systems. It discusses how existing Canadian and international water quality guidelines and scientific evidence guide public health decisions concerning the safety of drinking water.

The major microbiological and chemical agents that can contaminate drinking water are discussed in detail, as well as the current evidence about how to help prevent those agents from entering or remaining in the water supply. The report discusses specific public health issues around each component of the water system, from source protection, to water treatment, to maintenance of the pipe infrastructure and distribution system, to the consumer's tap. Finally, the report will detail a series of recommendations that can be used as a blueprint to focus our efforts on the most urgent and correctable problems that will have the greatest returns in terms of improved public health. If the recommendations are implemented, we are certain there will be continued improvement in drinking water quality and reduced illness in British Columbia.

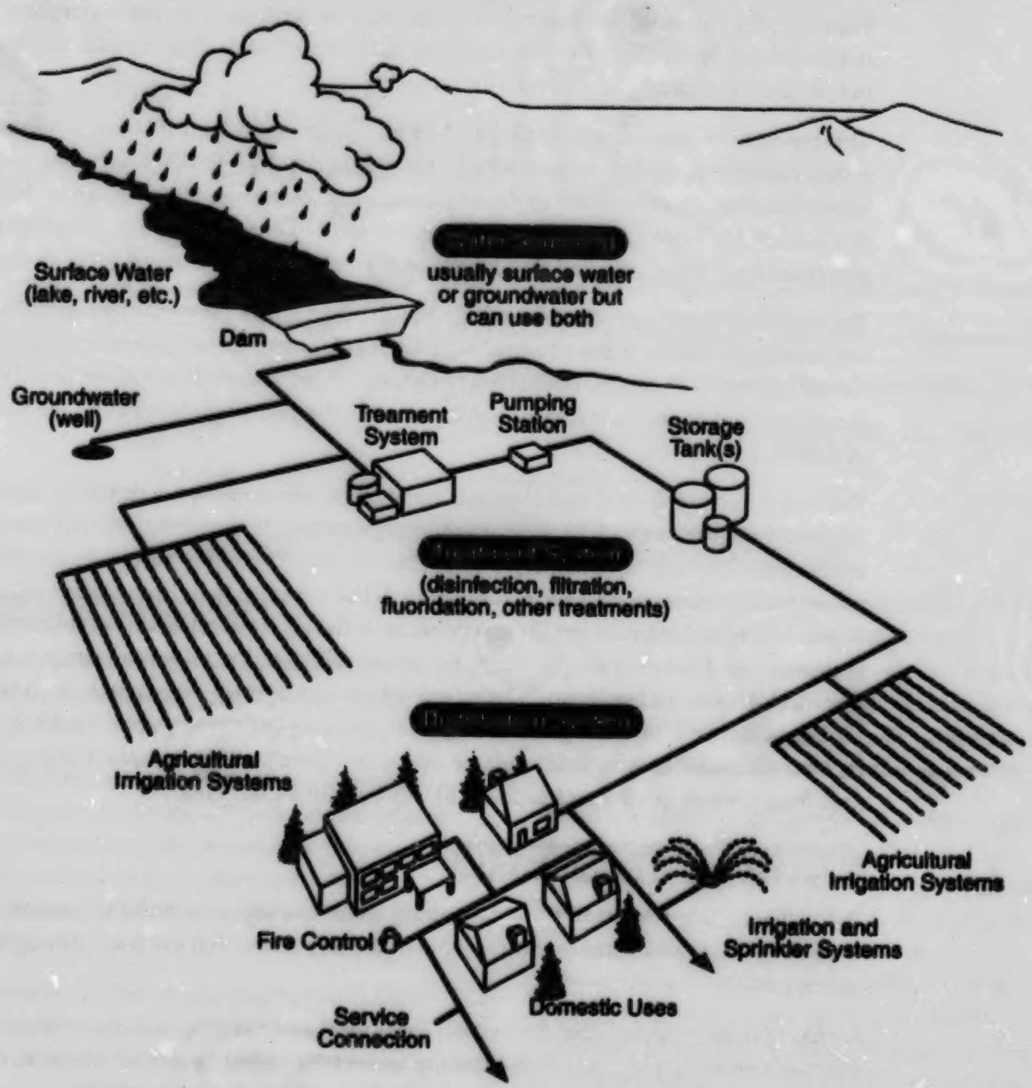
How Water Systems Work

Before beginning our discussion of drinking water quality, it is useful to consider how a water system works and to define some of the key terms that are used throughout this report.

Drinking water is water used for human consumption, food preparation, or other normal household purposes. Safe drinking water (also called "potable" water) is water that is safe to drink and fit for domestic purposes without further treatment.

A water (or waterworks) system is a system of water supply, including its source, treatment, storage and distribution facilities, where drinking water is provided for domestic purposes. The drawing on the following page shows some of the components of a typical water system (Figure 1).

[illegible] Treatment and Distribution Systems


Water Source
usually surface water or groundwater but can use both
Surface Water (lake, river, etc.)
Dam
Groundwater (well)
Treament System
Pumping Station
Storage Tank(s)
Treatment System
(disinfection, filtration, fluoridation, other treatments)
Agricultural Irrigation Systems
Distribution System
Agricultural Irrigation Systems
Irrigation and Sprinkler Systems
Fire Control
Domestic Uses
Service Connection

Each water system receives its water from one or more sources. Three-quarters of British Columbia's water supply comes from surface water—lakes, streams, creeks, rivers or rainfall. Because it is open to the atmosphere, surface water is particularly vulnerable to contamination by the actions of humans or animals or by natural events in the watershed such as landslides or extreme runoff from heavy rain. The rest of our water comes from groundwater—water that comes from either wells or springs, which are fed by underground water sources called aquifers. Some groundwater comes from deep, confined aquifers that are not subject to surface contamination, although the water may contain high levels of naturally occurring elements such as arsenic. Other underground sources are unconfined and are replenished by surface water. Leaching of contaminants, such as nitrates or bacteria, can taint these. Poor well construction practices are also a cause of contamination, as are improperly capped or abandoned wells.

After entering the water system, water undergoes one or more types of water treatment. Filtration is a purification method that removes soil particles and plant material that can interfere with disinfection. Filtration also removes parasites that are not killed by disinfection. Chlorine and/or other disinfectants are added to the water, killing many of the micro-organisms that cause disease.

After treatment, water is stored and transported to customers through a distribution system that reaches homes, schools, hospitals, fire hydrants, irrigation systems, and other users through "service connections." Contamination can occur during storage or distribution, for example, through the re-growth of microbes in the pipes, backflow of contaminants from cross-connections, backsiphonage, infiltration or unprotected storage facilities and during repairs and construction.

Historical Role of Public Health in Safeguarding Water Supplies

The importance of clean water to the health of the population has been recognized since ancient times. Various forms of water treatment were described in early Sanskrit and Egyptian writings. Hippocrates, 2400 years ago, recognized water as essential to human health and recommended rainwater be boiled and strained. However, it wasn't until widespread urbanization during the Industrial Revolution that the realization emerged that public water supplies could transmit disease and could be the source of devastating infectious outbreaks, such as typhoid and cholera (National Research Council, 1977).

In one of the earliest and still classic cases of epidemiology, which occurred before the germ theory of disease was established, London physician Dr. John Snow concluded in 1854 that a section of the London water system was transmitting cholera. By plotting cholera deaths on a map of the city, he showed that residents in a borough served by a water pump (the Broad Street Pump) whose source was a section of the Thames River polluted with sewage had an extraordinarily high incidence of disease. In contrast, residents in the same neighbourhood served by a pump drawing water upstream on the Thames, unpolluted by sewage, had an extremely low incidence of cholera (National Research Council, 1977; Last, 1997).

By the early 20th century it was established that various forms of water filtration, along with the addition of chlorine to the water supply, could all but eliminate the scourges of cholera and typhoid and other infectious agents from the water. In summarizing the ten greatest achievements in public health this last century, the U.S. Centers for Disease Control cited the provision of clean drinking water as one of the prime reasons for the dramatic reduction in deaths and illness from infectious disease (Centres for Disease Control and Prevention, 1999). According to the U.S. National Academy of Engineering, water treatment ranks fourth among the greatest engineering feats of the 20th century (National Academy of Engineering, 2000).

But despite these significant advancements, the threat to public health from microbiological contamination of water has not been removed entirely. In fact, in the late 1980s and 1990s, a series of outbreaks of waterborne illnesses, particularly from the protozoa *Giardia* and *Cryptosporidium* around North America, along with the emergence of new toxin-producing strains of bacteria that can be carried in water, such as *E. coli* O157:H7, has renewed the concern for the safety of our water supplies.

[illegible]

Since 1983, the Provincial Health Officer has been required by the *Health Act* to report annually to British Columbians on their health status and on the need for policies or programs that will improve their health. Some of the reports to date have given a broad overview of health, while others have focused on particular topics such as women's health, child health, or immunization.

Drinking water quality provides the focus for this year's annual report.

Copies of Provincial Health Officer's reports are available free of charge from the Office of the Provincial Health Officer, (250) 952-0876, http://www.healthplanning.gov.bc.ca/pho

For a number of years, the Provincial Health Officer, provincial government ministries, local health authorities, and the B.C. Centre for Disease Control have all been reviewing the measures that need to be in place to prevent outbreaks of waterborne parasitic disease and to manage emerging health risks in our water.

A 1999 report by the Auditor General found that British Columbia's drinking water sources were showing signs of strain. The report concluded that B.C. was not adequately protecting drinking water sources from human impacts, and that this could have significant cost implications in the future (Office of the Auditor General, 1999). Following the Auditor General's report, the provincial government asked the Provincial Health Officer to develop a report examining the full spectrum of water issues from source to tap. The report was well under way when events in the small Ontario town of Walkerton in the late spring of 2000 gave the report increased impetus and brought home to governments and the public across the Canada the gravity of the water issues which confront us.

Ensuring safe drinking water is a considerable challenge, because there are literally thousands of different water systems in British Columbia—more than 3,000 public and community water systems under provincial jurisdiction and 468 small First Nations water systems under federal jurisdiction. While water systems share some common features, individual water systems are designed in different ways and will face specific issues and challenges. Furthermore, the provision of safe drinking water is not a static practice, but involves the dynamics of new technology and demands placed by a growing population.

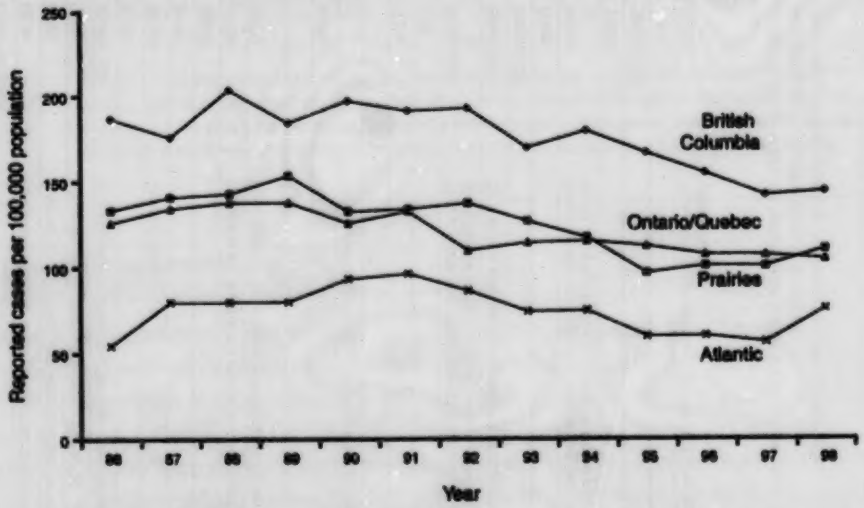
In general, most of the time, British Columbia's water is safe to drink, and many improvements have been made to water systems over the years. On the other hand, British Columbia received barely a passing grade in the first-ever survey of how Canadian provinces and territories are doing in protecting their drinking water (Christensen & Parfitt, 2001).

When Water Systems Fail

The risks to health from contaminated water in B.C. are not merely theoretical. Waterborne illness has been and continues to be a serious public health concern in B.C., affecting the health of the population and the economy of the province.

For a number of years, B.C. has had the highest rate of enteric (intestinal) illness of all the provinces in Canada (Figure 2). Since 1980, there have been 29 confirmed waterborne disease outbreaks, by such microbial agents as *Giardia*, *Cryptosporidium*, *Toxoplasma* and *Campylobacter* (Table 1). Many of the outbreaks were the result of water system failures or the absence of adequate treatment. It must be stated bluntly that in many areas of the province, B.C. has been under-treating its water for years. The outbreaks have resulted in tens of thousands of people getting sick, experiencing mild to extreme gastrointestinal discomfort, and missing work. The outbreaks may have contributed to a premature death or worsening of disease for vulnerable populations, such as the frail elderly or people with AIDS.

Figure 2: Enteric (Intestinal) Disease Rates 1986 - 1998



Diseases: Total reported cases of amoebiasis, campylobacteriosis, giardiasis, hepatitis A, listeriosis (all types), paratyphoid, salmonellosis, shigellosis, typhoid, and verotoxigenic E. coli. Reported cases from Health Canada, Disease Surveillance On-Line, http://www.hc-sc.gc.ca/hpb/lcdc/webmap/index.html. Population estimates from Statistics Canada, Demography Division; data obtained from the Health Data Warehouse, B.C. Ministry of Health Services.

Table 1 Waterborne Disease Outbreaks in British Columbia 1980 - 2000

Year	Location	Local Health Authority	Organism	Number of cases [1]			Suspected source	Preventability
				Lab Confirmed	Clinical cases	Epidemiological estimate		
1980	Nakusp	Kootenay Boundary	Campylobacter	12		800	Wildlife	
1981	100 Mile House	Cariboo	Giardia	69			Beaver	Coliform monitoring did not detect the parasite. Could not have been prevented, given testing requirements at the time.
1982	Kimberley	East Kootenay	Giardia				Wildlife	Preventable with better source protection and enhanced treatment. [3]
1984	Chilliwack	Fraser Valley	Salmonella	82			Broken watermain	
1985	Creston	East Kootenay	Giardia	72			Beaver	Preventable with better source protection and enhanced treatment. [3]
1986	Penticton	Okanagan Similkameen	Giardia	362			Beaver	Enhanced water treatment would have prevented the outbreak.
1986	Penticton	Okanagan Similkameen	Giardia	109	497	3,125	Beaver	Enhanced water treatment would have prevented the outbreak.
1987	Black Mountain	Okanagan Similkameen	Giardia	60			Wildlife/cattle	Enhanced water treatment would have prevented the outbreak.
1987	Kamloops	Thompson	Campylobacter				Wildlife	
1988	Near Lytton	Thompson	Salmonella				Wildlife	Caused by human error.
1990	Kitimat	North West	Giardia	28			Beaver	
1990	Creston	East Kootenay	Giardia	130			Wildlife	
1990	Fernie	East Kootenay	Giardia	50			Wildlife	Preventable with better source protection and enhanced treatment. [3]
1990	West Trail/Rossland	Kootenay Boundary	Giardia	>40			Wildlife	Preventable with better source protection and enhanced treatment. [3]
1990	Matsqui	Fraser Valley	Not identified					
1991	Barriere	Thompson	Giardia	25			Wildlife	
1991 *	Granisle	Northern Interior	Not identified					Avoidable with better treatment. Chlorination has since been employed.
1991 *	Fort Fraser	Northern Interior	Not identified					
1992	Kaslo	Kootenay Boundary	Campylobacter	10			Wildlife	
1993	Fernie	East Kootenay	Campylobacter	35			Cattle	
1995	Victoria	Capital	Toxoplasmosis	110		3,000	Cats/cougar	Thought to have been caused by a shallow reservoir, high intake pipe, high presence of cats propagating the protozoa. Reservoir has since been closed and the cats removed.
1995	Revelstoke	North Okanagan	Giardia [2]	62			Beaver/wildlife	Could not have been foreseen. A membrane filtration plant has been installed.
1995	Revelstoke	North Okanagan	Campylobacter [2]	71			Beaver/wildlife	
1996	Cranbrook	East Kootenay	Cryptosporidium	29	107	2,097	Calves	
1996	Kelowna	Okanagan Similkameen	Cryptosporidium	177		10,000	Human	Thought to have been caused by contamination from human sewage or other human source. There is still uncertainty about the original source of contamination.
1996 *	Valemount	Northern Interior	Giardia	10			Wildlife	
1997	Princeton	Okanagan Similkameen	Unidentified virus	146			Sewage break	
1998	Chilliwack	Fraser Valley	Cryptosporidium	19			Cattle	
1998	Camp Malibu	Coast Garibaldi	Campylobacter	26			Wildlife	Preventable if water had been disinfected or if camp management had adequately informed campers.

* Suspected outbreaks.

Outbreaks in which contaminated water was the likely source, based on the medical health officer's assessment of the evidence.

[1] Number of cases lab confirmed, physician confirmed, and total estimate. Some outbreaks were known to have occurred despite the absence of data. The epidemiological protocol was not in place prior to 1993.

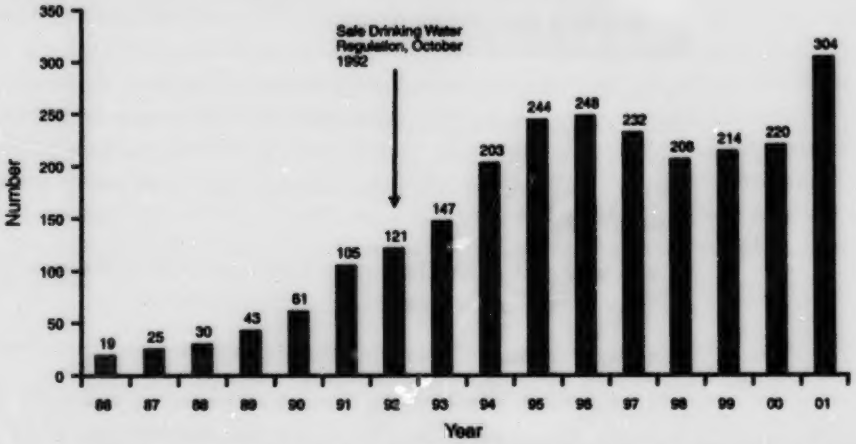
[2] 9 cases of *Yersinia* and 4 of *Cryptosporidium* were identified. These organisms may have been at background levels, but were identified due to increased laboratory surveillance.

[3] These outbreaks occurred prior to the Safe Drinking Water Regulation. Enhanced treatment was recommended by the chief environmental health officers, but recommendations were not implemented.

Sources: Public Health Protection, B.C. Ministry of Health Services and Laboratory Services, B.C. Centre for Disease Control.

In August 2001, 304 communities in B.C., or ten per cent of the water systems, were under boil-water advisories as a result of the water not meeting minimum standards for treatment and/or the presence of fecal or total coliform bacteria in water samples (Figure 3). This number is much higher than most other provinces in Canada (B. Boettger, personal communication, July 10, 2001). Most of these advisories were on water systems serving between 15 and 5,000 people and as such, represent fewer than one per cent of the B.C. population. Nevertheless, it is clear that more can be done to reduce the incidence of boil-water advisories in the province and to minimize our reliance on individual households boiling water as a *de facto* form of water treatment.

Figure 3: Boil-Water Advisories, B.C., 1986 - 2001



This chart shows the number of advisories in place at one point in time each year. In August 2001, there were 304 advisories, affecting about 10 per cent of the 3,016 water systems and one per cent of the provincial population. The increase in boil-water advisories in recent years is due in part to the Safe Drinking Water Regulation and increased emphasis on testing and reporting, which leads to identification of more unsafe water supplies. Source: Public Health Protection, B.C. Ministry of Health Services.

Lessons of Walkerton

During a period of heavy rain in May 2000, runoff from a farmer's field became contaminated with cattle manure and seeped into one of the wells that fed the Ontario town of Walkerton's water supply. The effluent carried a relatively new, toxin-producing strain of *E. coli*, called *E. coli* O157:H7. Evidence emerging from an inquiry into the outbreak (the Walkerton Inquiry) has revealed that not only was one of the town's wells shallow and vulnerable to contamination, but the individuals working for the local public utilities commission were not adequately trained nor even cognizant of their duty of care. Test results were ignored, chlorination was haphazard, communication with the local public health official was neither systematic nor honest, and prompt communication with the public did not occur. The results were disastrous, and seven people died. Walkerton has proved that complacency concerning our water systems does not simply increase the risk of stomach upset or missed days of work; complacency can kill.

The Ontario Independent Commissioner (the Walkerton Inquiry) has held extensive hearings and received submissions. Results of the Commission's review is expected in the spring of 2002.

The lesson of Walkerton is that we must be ever-vigilant about the integrity of our water supplies. There is no way to ever ensure "zero risk"—contamination can occur before testing reveals its presence or our testing may not detect agents capable of causing disease. But we can have systems in place that adequately foresee and attempt to minimize the chance of contamination. We can have regular and systematic surveillance so that if contamination or inadequate treatment occurs, prompt and aggressive action removes the threat and also effectively, honestly and quickly alerts the public to prevent widespread illness.

Recent Action in B.C.

In October 2000, the provincial government undertook to develop a drinking water protection plan to help improve drinking water quality in B.C. The government, with input from environment, public health and water quality experts, based on the multi-barrier approach, identified four measures that must be in place to ensure that drinking water is safe:

- Source protection. There must be management of the water source through effective controls over land uses to reduce contamination;
- Water treatment. There must be appropriate water treatment;
- Safe distribution systems. There must be sound, well-maintained and safe water distribution systems, so that water does not become contaminated in its delivery; and
- Effective monitoring. There must be effective monitoring of water quality and enforcement of standards.

A draft Drinking Water Protection Plan was drawn up that incorporates these four measures and outlines a series of possible steps that could be taken in each area. During January and February of 2001, a series of information sessions and public consultation forums were held around the province to solicit input on the plan from water users, water providers and the public in the regions. The resounding message from the consultations was that the public wants more to be done to protect drinking water quality in the province: stronger legislation, more effective source protection, and more money for infrastructure and safe drinking water programs (Praxis Pacific, 2001). Based on the consultations, the *Drinking Water Protection Act* was developed and received Royal Assent on April 11th 2001. The new Government is reviewing this legislation to determine if there is a need for modification.

▶ **See *Drinking Water Protection Act*, page 32.**

The multi-barrier approach is a good start for the protection and improvement of the B.C. drinking water supply. While water quality issues are evolving every day in B.C. and Canada, this framework will not become outdated. Indeed, it is the backbone of any safe water system and will serve us well into the future. We recommend the development of a HACCP process to address the multi-barrier approach in a more systematic way.

▶ **See HACCP page 77 and recommendation 14.**

This Provincial Health Officer's report on Drinking Water Quality that outlines the public health perspective on drinking water is intended to complement the other government actions that have been taken. While issues continue to evolve and the implementation of the legislative framework is being reviewed, this document is meant to serve as a reference that will remain relevant for at least 10 years in B.C. It aims to delineate the various public health risks from contaminated or inadequately treated water and what can be done about them. Along with learning from the experience of Walkerton, we have studied experiences in other jurisdictions (Europe, U.S. and Australia) on the controls needed to prevent and correct outbreaks of illness from drinking water. The recommendations reflect the best advice available at this time. Taken together, these recommendations, if followed, will assist B.C. to take practical and positive steps to further ensure the high quality of our drinking water supplies for all our citizens.

Regulation and Management of B.C.'s Water Systems

The primary responsibility for safe drinking water lies with the supplier (sometimes called the purveyor) of water. This chapter describes the role of the regulators (local health authorities, government ministries) and the provincial, national, and international organizations that are involved in setting standards. This chapter also recognizes the role of individual consumers in preventing waterborne illness.

Roles and Responsibilities

The delivery of safe drinking water from the source to the consumer is a complex process involving many players. Government, various agencies and authorities, water suppliers, and consumers have interests and responsibilities in one or more steps in the process.

Water Suppliers

Water suppliers are people or organizations that provide water to the public or to communities. Water suppliers can be a local or regional government, a water board or company, or an individual.

Water suppliers have ultimate responsibility for delivering safe water to the consumer. Their responsibilities are outlined in B.C.'s Safe Drinking Water Regulation.

Local Health Authorities

Local health authorities are responsible for protecting the public from waterborne illness. At this time 18 regional health authorities in the province—11 regional health boards and seven community health services societies, each with responsibility for a specific geographic area, employ the following public health officials, who each play a role in ensuring the safety of drinking water:

- Medical health officers, who are medical doctors trained in public health and appointed by Order in Council. They have the legislative authority under the *Health Act* to protect public health including controlling infectious disease outbreaks and preventing waterborne illness. There are 18 medical health officers in the province.

- Environmental health officers, who are also called public health inspectors, have legislative authority under the *Health Act* and carry out the requirements of the Safe Drinking Water Regulation as well as other public health regulations. There are 250 in the province. They inspect and monitor water systems and provide operating permits for all public and community water systems.
- Public health engineers, who are licensed professional engineers, have legislated authority under the Safe Drinking Water Regulation. There are seven public health engineers in the province. They issue permits for construction, alteration, or extension of water systems, provided the applicant has submitted appropriate plans and water quality analysis for the water source. The public health engineers also inspect existing water systems to assess risks and identify deficiencies, and, working with the local environmental health officers, to follow up any problem to find solutions or take appropriate actions.

1. *Drainage, Ditch and Dyke Act*
2. *Environment Management Act*
3. *Environmental Assessment Act*
4. *Forest Land Reserve Act*
5. Private Land Forest Practices Regulation
6. Forest Practices Code
    - Range Practices Regulation
    - Operational Planning Regulation
    - Forest Road Regulation
    - Timber Harvesting Practices Regulation
    - Silviculture Practices Regulation
7. *Health Act*
    - Sanitary Regulations
    - Sewage Disposal Regulation
    - Safe Drinking Water Regulation
8. *Local Government Act*
9. *Mines Act*
    - Mineral Exploration Code
10. *Range Act*
11. *Waste Management Act*
12. *Water Act*
13. *Water Protection Act*
14. *Water Utility Act*
15. *Drinking Water Protection Act*

For more information about B.C. legislation and B.C. ministry responsibilities, see Appendix B for web sites.

The medical health officers, environmental health officers, and public health engineers are together responsible for ensuring public health protection at all public and community water systems from intake to tap. They also have responsibility for on-site sewage disposal systems and any sanitary issues that may contaminate water supplies.

Throughout Canada, approval for the design and operation of water treatment facilities is regulated by provincial environment agencies. British Columbia is unique in that health officials, employed by local health authorities, are the regulators. Only one other jurisdiction in Canada, New Brunswick, currently empowers health officials to regulate drinking water.

Provincial Government

The provincial government has overall legal authority and responsibility for drinking water in British Columbia. After considering recommendations from national and provincial experts, the provincial government decides which water protection programs it will implement and fund. The provincial government also makes laws and regulations about drinking water and the prevention and control of waterborne diseases.

The Ministries of Health Services and Health Planning play a role in directing and establishing general public health drinking water policies and guidelines for medical health officers, environmental health officers, and public health engineers. The ministries encourage consistency across the province, while recognizing the discretionary powers of the local public health officials.

In particular, the Public Health Protection Branch, Ministry of Health Services, is responsible for the development and implementation of provincial legislation, policies, and program standards relating to drinking water quality. It has been actively involved in amendments to the Safe Drinking Water Regulation and the development of the *Drinking Water Protection Act* (April 2001). The Branch participates in inter-ministry water issues committees and is a member of the federal/provincial committee that oversees the updating of the *Guidelines for Canadian Drinking Water Quality*.

Working with community partners such as the B.C. Water and Waste Association and the Ministry of Water, Land and Air Protection, the Public Health Protection Branch has developed and carried out well protection workshops. A curriculum for water system operator training has been developed, and workshops are planned to implement the training. The Branch has also developed a booklet to help small waterworks operators develop an emergency response plan, as required under law, to which they can refer in case of an emergency that might present a threat to the health of people drawing their water from that system.

The Public Health Protection Branch collects data on water systems in B.C. and develops policies and guidelines for local health authorities, who are responsible for the direct delivery of programs and the prevention of water-related diseases. Four guidelines have been completed (boil-water advisories, bulk water, disinfection, and disinfection waiver), and nine others are in draft form, including terms and conditions of an operating permit, turbidity, source water and potability, and waterworks construction guidelines.

[illegible]

The province of British Columbia implemented a new government structure on June 5, 2001. The changes affected the organization of most ministries, including those responsible for health and the environment.

The Ministry of Health Planning and the Ministry of Health Services were established. Prior to the restructuring, their responsibilities were carried out by a single ministry, the Ministry of Health and Ministry Responsible for Seniors.

The Ministry of Water, Land and Air Protection Protection was established, with responsibility for environmental protection. Strategic planning functions from the former Ministry of Environment, Lands and Parks and other resource ministries were brought together under a new ministry, the Ministry of Sustainable Resource Management.

For full description of B.C. Government ministries and their responsibilities see Appendix B for web site.

The Provincial Health Officer, whose Office reports to the Minister of Health Planning, is the senior medical health officer for British Columbia. The Provincial Health Officer provides advice on drinking water quality to government ministries and works closely with the Ministry of Health Services, the B.C. Centre for Disease Control, medical health officers, and other health officials to fulfill their legislated health protection and disease control mandates. Duties of the Provincial Health Officer are outlined in the *Health Act*.

The Ministry of Water, Land and Air Protection Protection plays the lead role for pollution prevention in water sources. This ministry monitors water quality in selected

B.C. surface waters. In 1996, it published the *B.C. Water Quality Status Report* to provide information to the public on the state of surface water quality in B.C. and then in March 2000 published the companion report, *Water Quality Trends in Selected B.C. Waterbodies* (B.C. Ministry of Environment, Lands and Parks, 1996; B.C. Ministry of Environment, Lands and Parks and Environment Canada, 2000).

The Ministry of Water, Land and Air Protection Protection also has numerous projects concerning protection and management of groundwater. It is conducting an inventory of B.C. groundwater sources, identifying and mapping aquifers. To date some 420 aquifers have been mapped. In conjunction with the Ministry of Health Services it has produced the *Well Protection Toolkit* along with other educational materials. Workshops on well protection have been held throughout the province.

One of the key legislative tools the ministry uses to prevent pollution of drinking water sources is the *Waste Management Act*. This legislation and its regulations regulate all point source discharges of industrial and municipal liquid waste to the environment. The *Waste Management Act* also delegates significant powers to regional pollution prevention managers to approve discharge and disposal permits and to issue pollution abatement and prevention orders.

The Ministry of Water, Land and Air Protection is taking the lead role in co-ordinating the other ministries on water quality issues. Since the 1999 Auditor General's Report, it chairs the Director's Committee on Drinking Water and with the Ministry of Health oversaw the government's Drinking Water Protection Plan, holding consultations around the province as well as spearheading the development of the *Drinking Water Protection Act*.

[illegible]

A community watershed is the drainage area of a stream or river above the most downstream point at which water is diverted for human consumption.

A water users' community must license the diversion under the *Water Act* for a waterworks purpose or for a domestic purpose. Alternately, the diversion can be licensed for another domestic or waterworks purpose, if specifically approved by both a Ministry of Forests regional manager and a designated Ministry of Sustainable Resource Management official. Usually, the drainage area must be smaller than 500 km².

The Ministry of Sustainable Resource Management was established in June 2001. This new ministry brings together the strategic planning functions from the resource ministries and the Land Use Coordination Office. The ministry will support the development and approval of land and water use plans. It is responsible for issuing water licences to surface water suppliers. It also oversees community watersheds defined under the *Forest Practices Code*.

Other government ministries also have roles in water issues. The Ministry of Community, Aboriginal and Women's Services works closely with the health ministries to identify and confirm priorities with respect to municipalities, improvement districts, and regional districts' activities as they relate to the *Health Act*. Community, Aboriginal and Women's Services also provides study grants and construction grants to improve water system infrastructure.

The Ministry of Forests plays an important role, in partnership with the Ministry of Water, Land and Air Protection Protection, in ensuring watershed protection on Crown lands and tenured private land, by way of administration of the *Forest Practices Code of British Columbia Act*. The Forest Practices Code establishes requirements for strategic and operational planning, and for forest and range management practices that protect an array of forest values. The Ministry of Forests ensures that proper planning is carried out, and that activities are conducted according to the plan, and regulatory requirements. While all water sources are to be considered and protected to a certain degree on all lands under the Ministry of Forests' tenure, an enhanced level of protection is afforded to community watersheds that are designated as such under the *Forest Practices Code*. There are 450 to 500 community watersheds in B.C. Many were designated automatically when the Forest Practices Code came into effect in 1995. Other community watersheds were/are designated by a Ministry of Forests regional manager, in consultation with a Ministry of Environment, Lands and Parks (now the Ministry of Sustainable Resource Management) environment official. The *Forest Practices Code* does not apply to privately owned lands, which comprise many of the community watersheds on Vancouver Island.

The Ministry of Agriculture, Food and Fisheries oversees safe farm practices, including publishing the *Environmental Guidelines for Producers*, which identifies safe manure handling, storm-water and waste-water management, pesticide handling, irrigation and other farm practices that might impact water supplies.

The Ministry of Energy and Mines is involved in strategic land use planning and is an advocate for responsible stewardship and development of underground resources. It develops broad management strategies, such as one for water management during mineral exploration.

The Ministry of Transportation implements guidelines and standards to prevent water pollution during highway construction and maintenance. It also is involved with subdivision approval.

The Environmental Assessment Office is a neutral provincial agency that coordinates assessments of the impacts of major developments in B.C. After reviewing any foreseeable health, environmental, or other impacts, the Office recommends to the Minister of Sustainable Resource Management to either grant or refuse a project approval certificate.

B.C. Centre for Disease Control

Independent from, but closely associated with the Ministries of Health Planning and Health Services, the B.C. Centre for Disease Control is responsible for the prevention, detection and control of communicable diseases in British Columbia. It provides the microbiological science on which many water policies are based. Its laboratory services division provides an extensive range of microbiological testing, including water testing for communities throughout B.C., specialized laboratory analysis, and Quality Assurance (an accreditation program for laboratories that perform microbiological water tests).

On behalf of the Provincial Health Officer the B.C. Centre for Disease Control leads the surveillance for waterborne disease. Research is being carried out to determine how on-going surveillance may be able to provide more timely indication of the presence of a waterborne outbreak or of ongoing waterborne infectious disease in the population. When a disease outbreak occurs, B.C. Centre for Disease Control epidemiologists assist the local health officials investigate the source and extent of the outbreak to determine its origin and to contain its spread. It undertakes numerous research projects to better understand waterborne pathogens and has taken a leadership role in the study of waterborne parasitic outbreaks.

▶ **See recommendation 16 and see Appendix B for B.C. Centre for Disease Control web site.**

Federal Government

Water systems for First Nations on reserve fall under the jurisdiction of the local band and the federal government. Federal environmental health officers employed by the First Nations and Inuit Branch of Health Canada, carry out inspection and monitoring, and some bands have health nurses or community health officers who take water samples for the band. Indian and Northern Affairs Canada publishes annual statistics on water delivery and water quality of each reserve (Indian and Northern Affairs Canada, 2001).

▶ **See First Nations Water Systems page 41.**

Local Government

Local government, based on responsibilities defined in the *Local Government Act*, has a major role in pollution prevention through land use planning and zoning, waste management, sewage treatment, and bylaws for stormwater management. Most local governments operate community water systems.

British Columbia Water & Waste Association

The British Columbia Water and Waste Association (BCWWA), a non-profit association with 3,500 members, is the official spokesperson for the water and wastewater industry in B.C. BCWWA's mandate is to promote understanding of water and wastewater issues and to encourage all industry members to upgrade their skill levels and training on an ongoing and regular basis.

BCWWA offers a variety of training programs, including seminars, conferences, and courses leading to certification for water system operators. It sponsors Safe Drinking Water Week and has 16 industry committees that work on issues such as drinking water quality, cross-connection control, water use efficiency, operator education, and youth education. BCWWA is affiliated with the American Water Works Association.

▶ **See page 28 and Appendix B for BCWWA web site.**

The Individual's Role

While numerous government ministries and agencies have a role in ensuring drinking water quality in B.C., individual users can also play a significant part. A citizenry that is knowledgeable about drinking water issues can help ensure high quality drinking water. An uninformed public, by either action or inaction, can cause contamination of its water supply.

To prevent waterborne illness, individuals and families can take the following actions:

- If you get your water from a well, get your water tested.
- Get a *Well Protection Toolkit* from your local public health office and follow its guidelines to protect your well from contamination.
- If you get your water from a water district or other supplier, find out who your water supplier is. Find out where the water comes from, what treatment is applied, how often it is tested, and whether there are any concerns about water quality.
- If your community has a boil-water advisory, treat water before drinking it.
- Contact your doctor or public health office if you or family members seem to develop a waterborne illness.
- Participate in community planning and local growth strategies that may affect water supplies.

Lead Agency or Collaboration?

At least ten provincial government ministries or agencies have interests and responsibilities in the regulation and management of water (Table 2). The long-standing division of duties and interests has been criticized as being a weakness of British Columbia's system.

One of the 25 recommendations in the 1999 Auditor General's Report on Protecting Drinking Water Sources was to "designate within government a lead agency for drinking water interests to co-ordinate government policy and action on drinking water issues" (Office of the Auditor General, 1999). In subsequent personal communication, the Auditor General clarified that this recommendation was primarily aimed at putting the concerns of water suppliers on equal footing with other major resource users:

> "The lead agency was to deal only with the economic interests of the suppliers, not the health protection of the consumers. We saw no reason to include health protection in the lead agency role, because regional health officials already took care of that function," said Auditor General Wayne Strelioff (personal communication, March 13, 2001).

Nevertheless, calls for a single voice and accountability on water issues were repeatedly raised by groups around the province during public and stakeholder meetings for the Drinking Water Protection Plan (Praxis Pacific, 2001).

In the past, two ministries have shared the bulk of the management duties: the Ministry of Health and the Ministry of Environment, Lands and Parks. The Ministry of Health was the lead for the broad health issues, while the local public health officials—the medical health officers, environmental health officers, and public health engineers—served as the lead for the detailed, site-specific issues of drinking water quality from the source to the tap. The Ministry of Environment, Lands and Parks was the lead agency for source water protection, through activities such as pollution prevention, setting ambient water quality guidelines, and monitoring and reporting on ambient water quality.

Responsibility	Federal Govt.	Provincial Government										Local Authority	
		SRM	EAO	MOF	MEM	MAFF	MOT	CAWS	WLAP	MHS	PHO	MHO	Local Govt
Source Protection													
• Pollution prevention	■			■	■	■	■	■	■	■		■	■
• information management		■							■				
• Water quality monitoring	■	■							■			■	■
• land use (crown)		■	■	■	■				■			■	
• land use (private)		■	■	■		■	■		■			■	■
• water allocation		■							■			■	■
• public education	■								■	■	■	■	■
• source guidelines	■								■	■		■	
• land use impact research	■			■					■	■			
Water System Management													
• drinking guidelines/ standards	■									■	■	■	
• infrastructure standards		■								■	■	■	
• infrastructure finance	■	■						■					■
• operator training/ certification		■						■		■		■	■
• monitoring												■	■
• remedial measures												■	■
• public education	■									■	■	■	■
• data management										■		■	
• health research	■									■	■	■	

SRM: Ministry of Sustainable Resource Management
EAO: Environmental Assessment Office
MOF: Ministry of Forests
MEM: Ministry of Energy and Mines
MAFF: Ministry of Agriculture, Food and Fisheries
MOT: Ministry of Transportation
CAWS: Ministry of Community, Aboriginal and Women's Services
WLAP: Ministry of Water, Land and Air Protection
MHS: Ministry of Health Services
PHO: Provincial Health Officer
MHO: Medical Health Officer

Prepared by: Directors' Committee on Drinking Water. Published with permission of Chair.

With the new government structure, some of the water-related duties have been assigned to new ministries. The Directors Committee on Drinking Water, established in 1999, has a mandate to coordinate government activities related to drinking water quality. Ministries and agencies currently represented on this Committee include:

- Ministry of Health Services
- Ministry of Sustainable Resource Management
- Ministry of Water, Land and Air Protection Protection
- Ministry of Community, Aboriginal and Women's Issues
- Ministry of Forests

Many jurisdictions across Canada and the United States share the responsibility for drinking water quality between health authorities and environmental agencies. With the complexity of water issues and multiple interests involved, a collaborative and cooperative approach is needed, in which roles are clear, and priority interests are well-defined. We are confident that a commitment to an integrated process, where health concerns are heard and heeded and funds are made available to ensure appropriate water treatment, will lead to improved water quality from source to tap in the province.

Following the Auditor General's Report, a Drinking Water Protection Plan was co-developed by officials in the Ministry of Health and the Ministry of Environment, Lands and Parks. This draft plan was taken around the province for stakeholder and public consultations. It culminated in the development of new legislation in Spring 2001 protecting drinking water quality. One of the key features of the *Drinking Water Protection Act* is the establishment of lead authorities on drinking water issues in the province.

The *Drinking Water Protection Act* is currently being reviewed. Whatever management model or approach is ultimately chosen, we believe that three points are critical:

(1) coordination and collaboration are essential, when so many players have vested interests in the resource;

(2) water management roles and responsibilities must be clearly spelled out; and,

(3) there should be a streamlined access point, so that the public knows whom to call when they have questions and concerns about their water.

► See recommendation 6.

Health concerns need to be heeded

In the past, there have been times when health concerns over activities threatening drinking water quality have not been addressed in a timely and appropriate manner. Responses to referrals from the Ministry of Forests and the Ministry of Environment to health officials' concerns for Community Watershed designations, watershed assessments and other watershed planning issues were not always thorough or undertaken in a manner that has been responsive to these concerns. Some of these problems were the result of overlapping jurisdictional boundaries.

Placing a priority on the safety of drinking water in legislation is an important step to further improve B.C.'s water quality. This will ensure that drinking water systems, which may be vulnerable to microbiological, physical and chemical contamination, will be sufficiently protected while still allowing for appropriate multiple use of water sources and watersheds. There are practical and simple actions that can be taken to help protect water sources, such as barring animal grazing, human trespass and other activities within a certain distance of a water intake. Road construction and logging practices can be conducted and regulated so as to prevent undue runoff into water sources.

▶ **See recommendation 1.**

Water Quality Guidelines: Standards, and Legislation

How do we know when water is safe to drink? What level of contaminants in water cause health problems and what levels are of little or no concern? Over the last 40 years a series of guidelines and standards have been developed in numerous international jurisdictions setting out what should and should not be in water. These standards and guidelines, based on scientific, medical and technical research and toxicological data, set numerical values for the maximum acceptable concentration of contaminants or suggest an aesthetic objective to ensure that water is pleasing to drink. These guidelines help public health officials and water suppliers assess the safety of drinking water. In some jurisdictions these numerical values have legal standing, while in others they are used simply as guidelines

▶ **See Chapter 4, Risks to Health from Drinking Water.**

U.S. Safe Drinking Water Act

In the United States, the *Safe Drinking Water Act*, passed by Congress in 1974, is the primary federal law that regulates the quality of Americans' drinking water. The act authorizes the U.S. Environmental Protection Agency to set national, health-based standards for drinking water quality to limit both naturally occurring and man-made substances from contaminating drinking water. The standards are mandatory across the country. States can apply to implement the *Safe Drinking Water Act* in their own jurisdiction, but they must adopt standards at least as stringent.

Over the past 25 years the *Safe Drinking Water Act* has been amended twice to include other requirements on behalf of the states, the U.S. Environmental Protection Agency, and the water provider. The most recent amendments in 1996 include mandatory annual reports by water suppliers to the consumer about the water they provide, mandatory operator training certification, and mandatory source water assessment programs by each state. Under the latest amendment, the U.S. Environmental Protection Agency must conduct a thorough cost-benefit analysis for every new standard that it sets, in order to determine whether the health benefits gained justify the cost of implementation.

The U.S. Environmental Protection Agency is often regarded as setting the most stringent standards. When it alters or reviews one of its maximum contaminant levels, other international jurisdictions often review their own standards.

▶ See Appendix B for U.S. Environmental Protection Agency Office of Water web site.

American Water Works Association (AWWA) Guidelines

The American Water Works Association has extensive guidelines for the management and operation of waterworks systems. Water utilities, public health officials, and engineers use them in ensuring the protection of drinking water sources. The association publishes a monthly journal, and the American Water Works Association Research Foundation, an associated organization, provides "cutting-edge" research information.

The B.C. Water & Waste Association (BCWWA) is an affiliate of the American Water Works Association. Membership in the parent organization gives automatic membership to the B.C. chapter. The BCWWA has taken a lead role in promoting supplier information and training programs and public education. It runs workshops and conferences and publishes a newsletter.

▶ See Appendix B for AWWA and BCWWA web sites.

Australia

In Australia, the National Health and Medical Research Council has recently released a document for public consultation titled *Framework for Management of Drinking Water Quality*. The Framework uses a preventive, risk management approach that is comprehensive from water catchment to the consumer's tap (NHMRC/ARMCANZ Co-ordinating Group, 2001).

The 12 elements of the Framework are:

- Commitment to drinking water quality management
- Assessment of the drinking water supply system
- Planning – preventive strategies for drinking water quality management
- Implementation – operational procedures and process control
- Verification of drinking water quality
- Incident and emergency response
- Employee awareness and training
- Community involvement and awareness
- Research and development
- Documentation and reporting
- Evaluation and audit
- Review and continual improvement

The Canadian Federal-Provincial Subcommittee on Drinking Water is considering the development of a similar framework for improving drinking water quality in Canada. The comprehensive approach in the Australian document is consistent with many of the recommendations in this Provincial Health Officer's report.

▶ See Appendix B for *A Preventive Strategy from Catchment to Consumer* web site.

World Health Organization

In 1958, the World Health Organization first codified a set of basic information on drinking water contamination to help countries establish national drinking water standards. In 1984, in its third revision, it was released as the *Guidelines for Drinking Water Quality*, emphasizing a risk-benefit approach in the formulation and enforcement of national standards. It is intended as a knowledge base to help countries define their own standards. Its latest revision occurred in 1993 and is now available.

▶ See Appendix B for web site.

Guidelines for Canadian Drinking Water Quality

First issued in 1968 and revised five times, the *Guidelines for Canadian Drinking Water Quality* are produced by Health Canada in cooperation with representatives from the health and environment ministries of the provinces and territories, under the auspices of the Federal-Provincial Subcommittee on Drinking Water. The guidelines identify microbiological, physical, chemical and radiological parameters that have been found in drinking water and that are known or suspected to be harmful.

The guidelines are reviewed periodically to reflect new water quality information, scientific research and epidemiological information, and to consider changes in other international guidelines such as those from the World Health Organization and the U.S. Environmental Protection Agency. The *Guidlines for Canadian Drinking Water Quality* were last updated in 1996.

▶ **See Appendix B for Health Canada web site.**

For most substances, the guidelines set the maximum acceptable concentration (MAC) that can be permitted in drinking water. The MACs are based on a review of scientific, medical and technological literature as well as data collected by researchers, toxicological studies, and epidemiological studies involving accidental human exposure. In situations where the scientific evidence is uncertain about the toxic levels of a particular substance, the guidelines adopt interim maximum acceptable concentrations, with a larger safety margin to account for the uncertainty. Substances that may impart unpleasant taste, odour, or appearance to water are given "aesthetic objectives." These substances may have health effects at high levels, but if aesthetic objectives are met, health is protected.

The MACs for chemical contaminants are typically 10 to 5,000 times lower than those at which any adverse effects on health have been observed during prolonged and repeated testing (Health Canada, 1993). The MACs are set low to allow for a margin of error and to allow for other possible sources of exposure, such as through food and air, since adverse health effects depend on the cumulative exposure.

MACs are also set low to protect from a lifetime exposure to the contaminant, not exposures of short duration, and to protect children, the elderly and others who may be more sensitive to the contaminant. While MACs for microbiological contamination should not be exceeded, the MACs for chemical contamination are set low enough so that occasional exposure to concentrations above the recommended maximum is unlikely to affect health. Prolonged or long-term exposure to any water with chemical or radiological properties that are consistently above the MAC levels should be avoided (Health Canada, 1993).

It is left to each province to decide whether to enforce the guidelines in whole or part and whether to enact them as law or simply use them as guidelines. Quebec, Nova Scotia, and Alberta have adopted all the guidelines into law as regulated standards. After Walkerton, the province of Ontario proclaimed the Water Protection Regulation in August 2000 and established its own list of standards, called the Ontario Drinking Water Standards, which are based on the Canadian guideline numbers. British Columbia, under its recently revised Safe Drinking Water Regulation, has adopted microbiological, health-related chemical and some physical standards into regulation. The decision to regulate all these guideline numbers will cause significant costs for water systems for testing alone. It is the Provincial Health Officer's opinion that to have every water system test for all these parameters is unnecessary. It will be less costly and continue to protect public health if discretion is provided to the local Medical Health Officer for chemical and physical standards based on a risk assessment of the water supply. The Regulation is being considered for modification at this time.

B.C. Safe Drinking Water Regulation

British Columbia first enacted the Safe Drinking Water Regulation, under the *Health Act*, in 1992. The regulation gives public health officials—medical health officers, environmental health officers, and public health engineers—certain enforcement powers to ensure a safe drinking water supply. The regulation can only be enforced on water suppliers—people or organizations that provide water for public use or to communities—and not private systems. Some of the regulation's stipulations include:

- The water supplier must provide safe drinking water to all users of a waterworks system.
- The water supplier must notify all users served by the waterworks of an existing or potential health hazard.
- If health officials have identified a waterborne disease, a water supplier must take immediate action to minimize the risk to the satisfaction of the medical health officer.
- Health officials may at any time attach terms and conditions to the operation of a waterworks system by the supplier, to which the water supplier must comply.
- The water supplier must test water in compliance with procedures established by the local health officials. The health officials determine the frequency and location of the tests as well as the specific parameters to be tested.
- The testing agency must report the results of all tests directly to the health officials, not just to the supplier. This is an important distinction from Walkerton, where the water supplier forwarded results to health officials only if they felt the results warranted it.
- The water supplier must disinfect all surface water, unless the medical health officer decides it does not need disinfection.
- The water supplier must have prepared a written emergency response plan approved by the health official. This plan will be put into effect in the event of an emergency affecting the waterworks system.

Boil-water Advisories

A boil-water advisory is a notice to all consumers supplied by a water supplier that the drinking water may be contaminated, warning them to boil or otherwise disinfect water before use. The advisory may be given by a water supplier or by order of the medical health officer when:

- **Total coliform and fecal coliform bacteria counts are greater then the limits prescribed in the Safe Drinking Water Regulation.**
- **A waterworks system using surface water or shallow wells does not disinfect their water supply.**
- **An elevated health risk exists because of a water system or treatment failure.**
- **Evidence exists of improper or irregular operation and maintenance practices of a water system.**
- **High turbidity exists in source or supplied waters.**
- **Reports of gastrointestinal illness raise suspicion of a possible waterborne disease outbreak.**

Boil-water advisories are usually temporary, but they may last for weeks, months, or even years if a situation is not addressed. In August 2001, 304 communities in B.C., or ten per cent of the water systems, were under boil-water advisories. Estimates show that 65 per cent of these advisories were issued to water systems that supply untreated surface water.

The high number of advisories is the result of many factors including: numerous small water systems without an identifiable supplier taking responsibility for proper water delivery; lack of funding mechanisms to support necessary infrastructure upgrades and training; and community aversion to chlorine and chlorination by-products.

The microbiological parameters from the *Guidelines for Canadian Drinking Water Quality* that have been enacted into B.C. law are those for total coliform, fecal coliform, and *E. coli* (see Total and Fecal Coliforms, page 49 and Enterohemorrhagic *E. coli*, page 50). Tests must have less than one fecal coliform and less than one *Escherichia coli* per 100 ml. For total coliform, a single test must have 0 total coliform per 100 ml and if more than one sample is taken in a 30 day period, 90 per cent of the samples must have 0 total coliform per 100 ml, and no sample must have more than 10 coliform per 100 mL. An amendment to B.C.'s Safe Drinking Water Regulation was enacted in April 2001. A further amendment was enacted in October 2001, removing some of the provisions enacted six months previously.

▶ See Appendix B for B.C. Safe Drinking Water Regulation web site.

The Safe Drinking Water Regulation has enabled many improvements to be made on water systems since 1992. There has been an increased emphasis on water testing and reporting, and the Regulation has given medical health officers and environmental health officers more clout to encourage communities to embark on water improvements. For example, in the North Okanagan Health Unit, prior to the Safe Drinking Water Regulation, almost 17,000 people were drinking untreated surface water. Now just 600 people are under a boil-water advisory, and another 1,000 people require a boil-water advisory when they use their backup source. Three new treatment plants have been installed, continuous monitoring put in place, and improved computerized data collection established (N. Clarkson, personal communication, March 15, 2001).

A list of waterworks improvement expenditures and a table showing the types of water improvements by geographical region may be found in Appendix D. These tables illustrate how the Safe Drinking Water Regulation has spurred water quality improvements around B.C., including the increased funding for infrastructure works and an increase in the number of places using chlorination, UV treatment, and ozonation. There has also been an increase in the number of filtration systems installed during this period.

However, the Regulation has had some shortcomings. The Safe Drinking Water Regulation should be enforced, but in practice, enforcement has not always been feasible due to lack of resources or political will. The greatest difficulty has been in applying the Regulation to small waterworks systems where there may be a lack of an identifiable owner, lack of access to funding to improve the system, and sometimes lack of community understanding or agreement that the water needs to be made safer. The community sometimes disagrees on what needs to be done or is not prepared to consider the additional cost of improving the drinking water quality.

Drinking Water Protection Act

The *Drinking Water Protection Act*, which was given royal assent on April 11, 2001, introduces new measures to protect British Columbia's drinking water. The *Act* does the following:

- Establishes central coordinators to provide provincial direction on drinking water issues.

- Creates community-based drinking water specialists (drinking water officers) who will be responsible for drinking water issues in each health region.
- Requires certification, qualification standards, and training of water systems operators.
- Requires water suppliers to assess their drinking water sources, to identify potential threats to public health, and to develop plans to manage those risks.
- Affirms the public's right to know about their drinking water by requiring that assessments, water monitoring results, and emergency response plans be made public.

Nineteen of the 104 sections of the *Act* (including amendments to the *Health Act*) have been brought into force. The remainder of the *Act* would require a Regulation to be implemented. The *Act* is currently under review by a panel appointed by the Minister of Health Services and the Minister of Water, Land and Air Protection.

▶ See Appendix B for B.C. Legislation web site.

Guidelines or Legislated Standards?

In recent years there has been debate about whether the *Guidelines for Canadian Drinking Water Quality* should be adopted into law in British Columbia. Frequently, environmental organizations and some members of the public promote the enactment of most or all of the Guidelines' numerical limits as province-wide standards. They believe that doing so would better protect water from source to tap and would provide stricter enforcement. There is the impression by some groups that other provinces, by entrenching the numerical limits in law, are doing more than B.C. to protect water quality. The Auditor General in his 1999 report recommended the province develop its own drinking water quality guidelines to ensure accountability. Proponents argue that standards, when they are not met, are drivers for the needed improvements on water systems. Standards that are not met can trigger a health risk assessment and appropriate action.

However, there is opposition among some health professionals and water quality experts to legislating standards. Based on the best available evidence, the vast majority of water-related illness are due to a small number of microbiological pathogens—*Giardia, Cryptosporidium, E. coli* O157:H7, *Campylobacter, Toxoplasma*, and viruses. There are no existing standards or good reliable tests for *Giardia, Toxoplasma*, or *Cryptosporidium*—the agents that represent the greatest risk to the health of the B.C. public. Therefore, focusing on across-the-board standards would not protect the public from the most important threats to drinking water quality in B.C. Those opposed to legislating standards also believe the cost of testing would simply divert money away from the true health risks from drinking water towards the repeated testing of water, forcing water suppliers to test for a string of chemical contaminants that are of very little risk in B.C. For example, just one analysis of all the contaminants listed in the *Guidelines for Canadian Drinking Water Quality* costs almost $3,000; this same amount of money could pay for two bacteriological tests a week for a year.

Many water experts are also opposed to legislation of all the standards because it removes the ability to apply site-specific solutions for each water system. For example, why should the Capital Regional District water system that supplies Victoria be forced to test regularly for arsenic and radon when these chemicals have almost no chance of contaminating the water supply there? Instead of irrelevant testing, that money could be put towards improving water disinfection or even building a filtration plant to remove protozoan cysts from the water, which pose a much greater risk to that population. In addition, there is concern that the Maximum Acceptable Concentrations for some contaminants are too stringent—they are set for a lifetime exposure—and ingesting water with a concentration above this level for a short time would not be hazardous to health. Temporary levels of contaminants above the Maximum Acceptable Concentrations would worry the consumer and force the water supplier to make expensive changes that don't actually produce better health outcomes. Those opposed to regulating standards believe B.C.'s system of delegating authority to local medical health officers, under the Safe Drinking Water Regulation, can provide site-specific risk assessment and individualized monitoring of relevant parameters.

A workable compromise can be reached in which some of the *Guidelines for Canadian Drinking Water Quality* parameters are enacted as provincial standards, and some are left to the discretion of the local medical health officers. Some new standards should be adopted, such as a test specific to *E.coli* in addition to the total coliform and fecal coliform standards. Water systems should have an initial test for all relevant Guideline parameters at least once, and then focus subsequent testing only on those parameters that exceed Guideline values and are of health concern.

Ideally, the Ministry of Health Services, in conjunction with the Ministry of Water, Land and Air Protection and other ministries, should form a panel with representation from scientists, regulators, environmental groups, water suppliers, and public health officials. This panel would review the pros and cons on legislating standards and advise which parameters to legislate. The panel should conduct research into other jurisdictions, such as Alberta, Quebec, Ontario, and Nova Scotia, to find where they are hindered and where having regulated drinking water standards helps them improve water quality. We need to be sure that further legislating standards is likely to provide additional benefits that outweigh the costs and that the proper balance between risk assessment and consumer confidence is struck. The panel should then recommend a course of action for the government, whether that is amending the existing Safe Drinking Water Regulation, revising the *Drinking Water Protection Act*, enacting new legislation, or developing practice guidelines.

▶ **See recommendations 1 and 9.**

Treatment Standards

One area in which standards can be applied is in treatment outcomes. Since the greatest risk to the health of the B.C. population from waterborne contaminants comes from protozoan parasites that are not easily detected in water, the greatest health benefits will come from putting in place treatment standards that target these risks.

Water treatment is the most effective means of protecting the public from water-related illness. Compared to many other jurisdictions, B.C. under-treats its drinking water and has for years. In recent years, the U.S. Environmental Protection Agency brought in the Enhanced Surface Water Treatment Rule to improve the control of microbiological pathogens, specifically *Cryptosporidium*. Aimed at water systems that serve more than 10,000 people, the rule puts in place a maximum contaminant level of zero for *Cryptosporidium*, stricter disinfection benchmarking, stricter rules for turbidity, and a requirement that all new reservoirs for finished waters be covered. The Surface Water Treatment rule means that most surface waters in the United States must now filter their water. It is estimated that the stiffer provisions will reduce *Cryptosporidium* disease by between 100,000 to 463,000 cases annually (Regli, Berger, Macler, & Haas, 1993). It is also expected that enhanced water quality will substantially reduce other waterborne pathogens, such as *Giardia* and bacteria.

Setting and implementing treatment standards would minimize the health risks that British Columbians face from waterborne contaminants. There should be standards that require:

- Assessment and rating of all water treatment systems in British Columbia with respect to their effectiveness against bacteria, viruses, *Giardia*, *Cryptosporidium*, and other pathogens found in B.C. source waters. Assessments should be done in a consistent and uniform way. This is generally done by specifying the log reduction achieved against different groups of pathogens

▶ See Log Reductions, page 85.

- A legally enforceable set of practice guidelines for use by medical health officers in deciding when, where, and how much additional treatment may be required for a particular system.

A time-line for compliance could be established that would focus attention on the highest risk water systems first and enable communities to plan and set funding priorities. Setting water treatment standards would also give water systems a target that could be used to measure, demonstrate, and report achievements in improved protection. It would provide consistency from region to region and provide certainty for local governments about what is expected for water quality.

Treatment standards are incorporated in the practice guidelines established by the Council of Public Health Engineers of B.C. These are legally enforceable if included in the operating permit required by the Safe Drinking Water Regulation.

▶ See recommendation 25.

▶ See Microbiological treatment standards—recommendation 10 and terms and conditions of operating permits—recommendation 23.

Inventory of B.C. Water Systems

What do we know about British Columbia's water systems? This chapter presents some of the facts and figures we have available, as well as some of the information gaps. There are about 3,016 water systems in the province today—an increase of 500 in the last five years. Water treatment beyond simple disinfection is expensive. Therefore, this chapter concludes by discussing the potential benefits and costs of water system improvements as well as mechanisms of funding water system improvements.

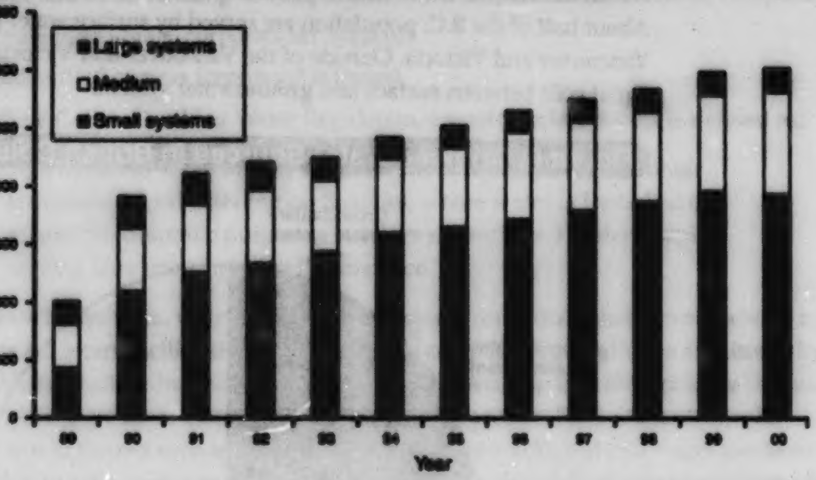
Large and Small Water Systems

Water systems are commonly classified according to their size, as measured by the number of connections or users served. B.C. had 3,016 water systems under provincial jurisdiction in the year 2000, and two-thirds of these were small systems serving two to 14 connections each.

British Columbia has three times as many water systems as it did in 1989. Most of the increase has been among small systems, which showed more than a four-fold increase over this time period (Figure 4). A portion of the increase is due to increased efforts to identify water systems and to record them in regional health information systems.

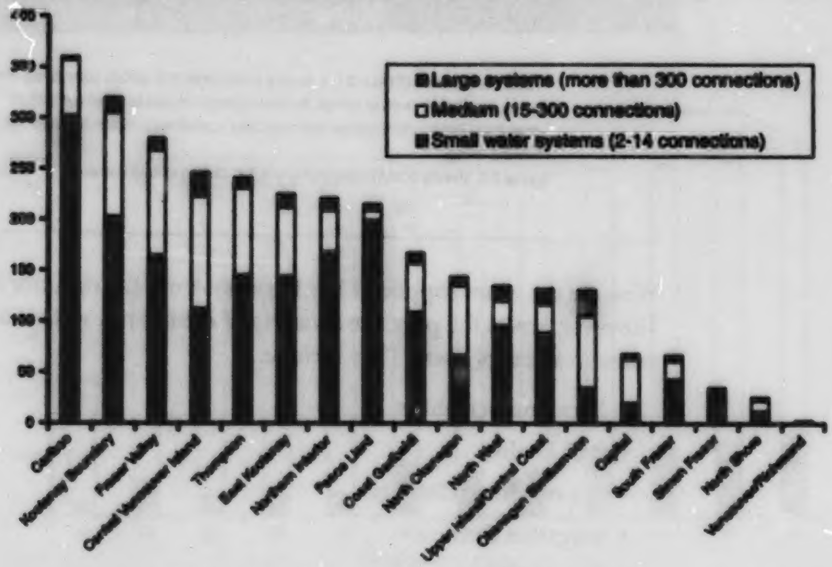
More than half of the B.C. population get their water from the two largest water systems: the Greater Vancouver Regional District system, which serves 18 municipalities and two million people, and the Capital Regional District on south Vancouver Island, which supplies a population of approximately 310,000. Not surprisingly, most of the small and medium-sized water systems are found in rural areas of the province. Of the local health authorities, Cariboo has the most water systems under its jurisdiction (360), followed by Kootenay Boundary (320), and the Fraser Valley (280) (Figure 5 and Appendix F).

Figure [illegible]



Water systems are categorized according to the number of connections: small (2 to 14 connections), medium (15 to 300), larger (more than 300 connections). Figures are as of March 31 each year and do not include First Nations water systems. Figures for 1989 to 1995 do not include former municipal health departments (Vancouver, Burnaby, North Shore, Richmond, New Westminster, Capital). Source: Public Health Protection, B.C. Ministry of Health Services.

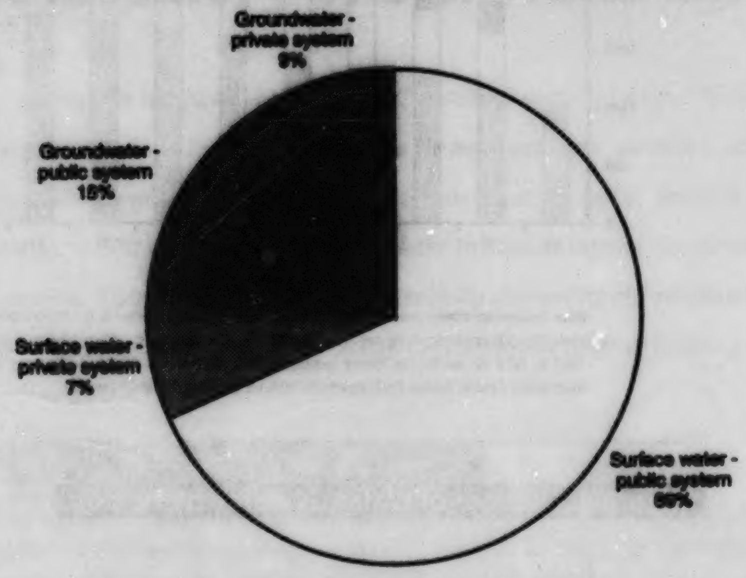
Figure [illegible]: Number of Water Systems by Region



Figures are as of March 31, 2000. Source: Public Health Protection, B.C. Ministry of Health Services. For additional regional data, see Appendix F.

Most British Columbians get their water from a public system of some type, while the remainder receive water from a private system that serves only one family (Figure 6). About half of the B.C. population are served by surface water public systems in Vancouver and Victoria. Outside of the Vancouver and Victoria areas, there is roughly an equal split between surface and groundwater systems.

Figure 6: Drinking Water Sources in British Columbia



- About three-quarters (76%) of B.C.'s drinking water comes from surface water (lakes, river, streams); the remainder comes groundwater (wells or springs, fed from underground sources called aquifers).
- Most (84%) British Columbians get their water from a public water system (a system that serves more than one single-family dwelling).

Source: B.C. Ministry of Water, Land and Air and B.C. Ministry of Health Services.

Who are the water suppliers? For larger systems, the operator is usually a municipality. However, across the province a variety of entities run waterworks and provide drinking water to a host of users. They include:

- Local municipalities
- B.C. Hydro
- Improvement districts
- Irrigation districts
- School districts
- Industries: sawmills, pulp mills, mines, logging camps, oil exploration camps
- First Nation band councils
- Resorts, restaurants, hotels, pubs

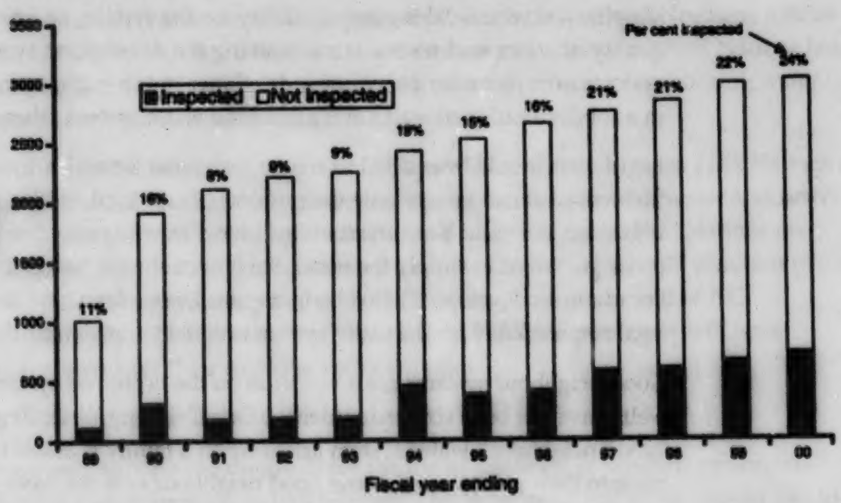
- Mobile home parks, RV parks, campsites
- Large and small housing developments, strata corporations, numbered companies
- Private individuals, corporations, societies
- Unidentified owners (orphaned systems)

Under the B.C. Safe Drinking Water Regulation, a waterworks systems is defined as:

> "the means of water supply including its source treatment, storage, transmission and distribution facilities, where water is furnished or offered for domestic purposes, but does not include a water supply serving only one single family residence."

Under existing statutes, water systems with a single connection that serve a school, a mall, a hotel, a care facility, day care, or logging camp are required to be monitored by the health authorities. In reality, this can be very difficult to do with regularity because some regions have more than 300 water systems to monitor. Environmental health officers aim to inspect each water system at least once a year, but that target has been impossible to achieve due to lack of resources and the demands of other programs such as sewage disposal permits and inspection of restaurants and other premises. Almost one-quarter (24 per cent) of the water systems received an annual inspection in 1999/2000, up from 11 per cent ten years ago, but still far below the target of 100 per cent (Figure 7). Given scarce resources, public health officials focus their monitoring efforts on the water systems that impact the largest number of consumers.

Figure 7: Water Systems Inspected by Environmental Health Officers B.C. 1989 - 2000



Number Inspected: The number of water systems that received at least one routine inspection during the fiscal year. The long-term target is for all waterworks systems to receive at least one inspection per year. Source: Public Health Protection, B.C. Ministry of Health Services.

It has been suggested that the threshold of regulation for a waterworks be increased to five, ten or even 25 connections, in part because of the difficulty of monitoring small systems. That, however, is not the solution. These small water systems serve children and families and individuals who need to have their health protected from waterborne illness and need to have water systems that have public accountability.

The Provincial Health Officer, therefore, recommends the regulation remain at one connection or more when that one connection serves more than a single family. At the same time, we should explore other options, such as the U.S. model in which drinking water standards apply to water systems differently based on their size and type. Small water systems are given special consideration and resources in the United States, to make sure they have the managerial, financial, and technical ability to comply with standards (U.S. Environmental Protection Agency, 1999).

▶ See recommendation 2.

In addition, British Columbia needs to have a system in place to prevent the continued growth in the number of small systems. Placing restrictions on water permits or only allowing new systems that link up with existing municipal water systems are possible approaches. Existing small systems should have financial encouragement, or the force of legislation, to have them amalgamate, wherever possible, with larger entities.

▶ See recommendation 3.

Orphaned and Good Neighbour Systems

One of the considerable problems of ensuring good drinking water quality in B.C. is the existence of waterworks in which there is no identifiable supplier. In parts of B.C., such as the Kootenays, some waterworks have up to 80 connections with no identifiable supplier—no one is taking responsibility for the system, no one is monitoring the quality of water, and no one is maintaining the distribution system. These orphaned systems arise, for example, when a developer puts a water system in place to service lots in a subdivision, then walks away from the water system when the lots are sold.

Legislation should be enacted to ensure that water licences are not granted in situations that will create and perpetuate the problem of non-legal entities. Whenever a water licence is granted, it should be to an identified owner or water supplier. If an owner or supplier no longer wants to supply the water, the licence should be legally passed to a new owner. For example, developers who obtain a water licence for a new subdivision must retain legal responsibility for the water system until they transfer the title to a new entity.

Good neighbour systems are a variation on the orphaned system. Private, single family wells have not been covered under the Safe Drinking Water Regulation. Typically, a "good neighbour" water system arises when a family is asked by neighbour if they can tap into their private well. Some good neighbour systems have grown so that 20 or 30 households or more are on a water system that is not being monitored for contaminants, maintained, or regulated. Conceivably, families may purchase their homes and not realize that their water comes from an unregulated and unmonitored source with no legal entity taking responsibility for the quality of drinking water being delivered.

British Columbia should work to eliminate the perpetuation of small systems that lack accountability and resources to ensure the safety of consumers.

▶ See recommendation 3.

First Nations Water Systems

In addition to the 3,016 systems monitored by local health authorities, there are about 468 First Nations' water systems, serving 16,025 households, that fall under the jurisdiction of the local band and the federal government (Indian and Northern Affairs Canada, 2001). Federal environmental health officers, who are employed by the First Nations and Inuit Health Branch (FNIHB) of Health Canada, carry out inspection and monitoring of First Nation's water systems. FNIHB conducts full chemical testing and analysis of drinking water every three years. Regular bacteriological testing, in accordance with the recommendations stated in the *Guidelines for Canadian Drinking Water Quality*, is supposed to be undertaken. However, lack of FNIHB resources to cover all the bands may mean that routine bacteriological sampling may not occur for several weeks, or longer. Some bands have health nurses or community health officers who take the water samples for the band. FNIHB does, however, have sufficient resources to test for contaminants that are not regularly analysed, should there be an indication that a particular substance may result in a negative health effect.

Federal drinking water standards for First Nations specify that all proposed new water systems meet the *Guidelines for Canadian Drinking Water Quality*. The provincial Safe Drinking Water Regulation under the B.C. *Health Act* is also followed, except in instances where it is less stringent than those the Guidelines. In terms of determining the appropriate level of water treatment for First Nations, it is up to each First Nation and its technical advisors, sometimes in collaboration with the local health authority to make the decision. Public health engineers employed by Indian and Northern Affairs Canada (INAC) review and approve plans for any water systems on First Nations land. Provincial public health officials are not involved in approving or monitoring water systems on First Nations reserves in B.C.

Indian and Northern Affairs Canada (INAC) provides funding to assist First Nations in the design, construction, and ongoing operation and maintenance of water and sewer services. Through INAC, funding has been made available for all First Nations on reserves to provide water filtration treatment. In B.C., there are now 27 filtration plants on First Nation reserves, compared with 11 filtration plants in the rest of B.C. communities. By 2005 it is estimated that all First Nations on reserves will have filtration systems for their drinking water supplies.

▶ See Filtration, page 89 and Table 6 (page 91).

There are currently no requirements for the use of qualified or certified personnel operating water systems on Indian reserves. This is an issue that INAC would like to address in partnership with provincial governments and First Nations. In B.C., INAC has developed a Circuit Rider training program which provides on-site training to First Nation maintenance personnel in the operation and maintenance of their water and sewage facilities. (N. Rayner, personal communication, March 15, 2001).

A recent report from INAC titled *Safe Drinking Water on First Nation Reserves—Roles and Responsibilities* outlines the roles of INAC, FNIHB and the provincial health authorities in Canada (Indian and Northern Affairs Canada, 2001).

INAC collects data about First Nations water systems in its community infrastructure database, and summary reports are produced annually. The most recent report showed that 81 per cent of housing units had water supplies that met the health-related requirements of the *Guidelines for Canadian Drinking Water Quality* (Table 3). Comparable data are not available for systems under provincial jurisdiction.

Number and per cent of housing units with water supply categorized as:

	Meeting requirements of				
Category	GCDWQ [1]	INAC [2]		Number	Per cent
1	Yes	Yes	Pressurized water supply	12,143	75.8%
1A	No	Yes	Pressurized water supply	2,769	17.3%
2	Yes	No	A supply that does not meet volume requirements	798	5.0%
2A	No	No	A supply that does not meet health or volume requirements	265	1.7%
3	No	No	No water supply	52	0.3%
			Total housing units	16,025	100.0%

[1] Water supply that satisfies the health-related requirements of the Guidelines for Canadian Drinking Water Quality, 5th edition (1993). A water system is not deemed inadequate because aesthetic objectives are exceeded.

[2] Water supply that satisfies the volume requirements of INAC Level of Service Standard (LOSS) for adequate hygiene and safety purpose.

Source: Indian and Northern Affairs Canada (INAC). *1999 Housing and Infrastructure Assets Summary Report*, page 18. http://www.ainc-inac.gc.ca/ps/ols/index_e.html

Information Gaps

Good, accurate information is essential to any decision-making and management. In monitoring B.C.'s water systems, those with responsibility under the *Health Act* (public health officials) currently rely on incomplete and sporadically collected information. The available information is about water-related illnesses and outbreaks, an annual count of boil-water advisories, and statistics collected (up until March 2000[1]) by environmental health officers as they carry out inspections and other duties.

While some statistics are available, the lack of basic, centralized data hampers the province from effective monitoring, research and improvement of the water supply. How many water systems use chlorine to treat their surface water? How many water systems simply deliver untreated surface water to consumers? How many systems have personnel who have undergone operator-training certification? These and other questions cannot be answered easily without phoning each health region and questioning the environmental health officer, public health engineer, or medical health officer—some of whom have more than 300 water systems under their jurisdiction. Table 4 shows some of the information gaps we currently have in British Columbia.

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[1] The Environmental Health Officers Computer System (EHOCS) and the Water Sampling Analysis Computer System (WSACS) are now obsolete. Most local health authorities are developing their own information systems using third-party software. The Public Health Data Requirements Project is examining data that the Ministry of Health Services requires from health authorities on a regular basis.

[illegible]

Topic	What we know	Examples of what we don't know
Water system characteristics	• There were at least 3,016 water systems in B.C. in March 2000. • Two-thirds of the water systems are small, serving two to 14 connections each.	• How many systems are there in B.C. today? • How many systems are "orphans" (no identifiable owner)? • How many systems have staff who have undergone operator training and certification?
Water sources	• About three-quarters of B.C.'s water supply comes from surface waters (estimate).	• What is the water source (surface water, groundwater, or both) and the population served by each system? • How many systems have had a sanitary survey done for their water source? • For each water system, what are the sources of potential contamination with pathogens? Is source water subject to periods of elevated turbidity? • What steps are being taken to reduce pathogens and turbidity in source water?
Water treatment		• How many water systems treat their surface water, and how many simply deliver untreated water to consumers? • For each water system, what types of treatment are in use? • How many log reductions does the treatment provide against viruses, *Giardia*, and *Cryptosporidium*? Does the medical health officer consider this adequate? • What are the levels of disinfection by-products? What is measured and how often?
Distribution system		• For each water system, what is the state of the distribution system? • Are there potential cross-connections? • How is the distribution system maintained?
Compliance with regulations, standards, and guidelines	• There were 304 boil-water advisories in place in August 2001.	• What are the reasons for the boil-water advisories? • How many waterworks systems comply with the B.C. Safe Drinking Water Regulation? • Which *Guidelines for Canadian Drinking Water Quality* levels are exceeded, and by how much?
Water-related illnesses	• More than 5,500 cases of intestinal infections are reported to public health authorities in B.C. each year. • 29 waterborne disease outbreaks are known to have occurred in B.C. in the past 20 years.	• How many of these illnesses are caused by contaminated water? • Other than during outbreaks, what is the level of water-related illness in B.C.? Is the trend improving, stable, or worsening?

Appendix E is a proposed data set for monitoring drinking water systems for B.C. If it were used by all health officials it would enable these information gaps and other questions to be answered regarding all the drinking water systems in B.C.

There are 3,016 identified water systems now in the province—an increase of approximately 500 in the last five years alone. Only the creation of a province-wide information system with a standard set of data for each water system will enable the provincial government to develop a comprehensive assessment of and to manage the province's drinking water assets and its quality. This will involve inter-ministry coordination, defining data elements and the methods of data acquisition (such as direct data entry by laboratories), and establishing effective data management—such as by linking, or becoming part of an existing database (such as that managed by the Ministry of Water, Land and Air Protection). There should also be linkage, using unique identifiers for water systems and mapping capabilities, to databases of uses that affect water source quality (such databases, for example, are maintained by the Ministry of Forests).

Other data to collect would be waterborne disease surveillance data and information on outbreaks and suspected causes. The collection of data on water quality problems attributable to forestry, cattle ranging, or other watershed use issues will be essential, to gain a better understanding of how frequently, and to what degree, these activities contribute to water quality problems.

British Columbia lags behind many other jurisdictions in the collection and reporting of drinking water statistics ▶ **For some examples, see Appendix B for web site listings for Newfoundland, Ontario, Quebec, and the U.S. Environmental Protection Agency.** Most B.C. health regions are implementing new databases for water systems and drinking water quality. This will provide an opportunity to close some of our information gaps. The draft data set outlined in Appendix E provides some basic questions that should be answered, such as the name and location of the source, other land usage in the watershed, the population the water serves, the methods of treatment, identified threats to the quality of water, etc.

During meetings of the Federal-Provincial Subcommittee on Drinking Water, which is responsible for updating and developing the *Guidelines for Canadian Drinking Water Quality*, B.C.'s input is sometimes limited because of the lack of availability of accurate data. For example, a number of guidelines are now being reviewed, including arsenic, disinfection by-products, and turbidity. B.C. does not have comprehensive data on the presence of these parameters in our drinking water sources, so it has been difficult to provide insight into the implications that changes to the maximum acceptable concentrations would have on B.C.'s drinking water systems.

An improved information system would enable the Ministries of Health Services and Water, Land and Air Protection to carry out periodic surveys with the assistance of the public health officials to determine the prevalence of various parameters in drinking water on all B.C. drinking water systems. Summary reports should be developed for public health officials and for the Federal-Provincial Subcommittee on Drinking Water and made publicly available for those interested.

▶ **See recommendations 17 and 28.**

Economics of Water Quality Improvement

The provision of safe drinking water is one of the most effective tools we have for maintaining health and preventing illness and death. With the exception of vaccines, no other intervention in the last century—not even antibiotics—has had such a major impact on people's health and survival (Plotkin & Plotkin, 1994).

Because of new technologies and our growing understanding of water-related diseases, new ways to improve drinking water quality are always being developed. New types of water treatment tend to be more complex and expensive to implement than traditional methods such as chlorination. One of the fundamental questions that must be asked is whether the amount of money needed to address this issue translates into considerable health gains for the population.

A recent study in the Greater Vancouver Regional District found that variations in drinking water quality accounted for 17,500 physician visits, 85 hospital admissions, and 138 pediatric hospital emergency room visits over a six-year period (Aramini et al., 2000). More studies are required that will fully estimate the health impacts associated with drinking water. However, the Greater Vancouver findings suggest that there are significant levels of illness—and associated personal and health care costs—that could be avoided through water system improvements.

The 1999 Auditor General's Report noted that if all the surface water systems in B.C. outside of the Lower Mainland and Victoria were to install filtration, the capital cost would be about $700 million and the operating cost about $30 million a year. That estimate may, in fact, be too low. Two billion dollars is the current estimated cost to move B.C. towards the U.S. standard of filtration of all surface water supplies (A. MacTaggart, personal communication, July 9, 2001).

Water treatment beyond simple disinfection is expensive. It is clear from a health standpoint that B.C. should be taking steps to add more filtration to its surface water systems to protect the public from waterborne illness, particularly *Cryptosporidium* and *Giardia*. However, the decision to spend money on filtration systems or any other water improvement methods (such as using a groundwater source) will ultimately be a political and economic decision, as well as a health decision.

It is interesting to note that communities and local governments that have been reluctant to spend money on adequate treatment often find the political and public willingness to make the investment after the population has been hit by a substantial waterborne disease outbreak. From the public health perspective, we should be preventing these outbreaks by proper treatment before they occur.

There are many ways of funding water quality capital improvements. In the past, the Ministry of Municipal Affairs (now the Ministry of Community, Aboriginal, and Women's Services) has issued grants and funding contributions for water and sewer system upgrades that met their approval. The projects are typically cost-shared up to a maximum of 50 per cent with local governments. Priority has been given to projects that protect human and environmental health and reflect innovative approaches and technologies. This cost-sharing program, however, has only been made available to municipal governments and regional districts. Smaller unorganized areas and irrigation and improvement districts are not eligible for funding assistance under this program, unless they are amalgamated with the local regional district or are annexed by an adjacent municipality. Privately owned public water systems are not eligible for funding assistance.

Between 1992 and 1999, the Ministry of Municipal Affairs spent $43 million in grants for municipal drinking water system improvements. Appendix D lists the projects, communities and sizes of grants that were received. According to this Ministry, since 1992, some $600 million has been available for construction of water treatment in the form of cost-sharing grants. The reason only $43 million was dispersed in matching grants for water treatment was because those were the only applications that were received (A. MacTaggart, personal communication, March 16, 2001). It would seem that the myth of B.C.'s pristine water perpetuates the belief at the community level that there is no need to embark on expensive water upgrades, even if there are matching funds available.

There are other ways of funding both capital and operating costs for drinking water systems. Other funding mechanisms include:

- The development of public/private partnerships in which a private company builds and runs the facility and charges back costs.
- Increased user fees collected by government—federal, provincial, or local—or by the supplier who may be public, not-for-profit or for profit.
- Private capital investment.

It is beyond the scope of this report to analyse the many ways of funding used in Canada or different parts of the world. It is not the Provincial Health Officer's role, nor expertise, to advise communities how they can pay for needed treatment upgrades to their water systems. Our role is to offer advice about how to protect the population from waterborne disease. From the public health perspective, it is clear that much of B.C.'s surface water requires more adequate treatment, particularly disinfection and filtration, to reduce the incidence of waterborne illness. The use of groundwater rather than surface water may be found to be an acceptable economic alternative. It is up to economists, elected officials, and the public to find the most cost-effective way to pay for it.

▶ **See key message 8 and recommendations 12 and 13.**

Risks to Health from Drinking Water

In this chapter we summarize the important public health risks from drinking water in British Columbia. Of the 29 waterborne disease outbreaks reported since 1980, more than half have been caused by parasites (Giardia, Cryptosporidium, Toxoplasma). Nitrates from livestock wastes, fertilizers, or septic tanks can filter down through soil and contaminate water, as can spills of chemicals. Naturally occurring chemicals such as arsenic cause contamination in some areas of the province. Turbidity (cloudiness) affects water quality in certain areas, usually on a seasonal basis.

For thousands of years, water has played an important role in the transmission of human diseases. Typhoid fever, cholera, hepatitis A, amoebic dysentery and other agents of gastrointestinal disease can be transmitted by water and have been responsible for millions upon millions of incidents of death and disease in the world's populations. While these agents still kill millions each year in developing countries, fortunately in developed nations good waste management, improved sanitation and the treatment of drinking water now control many of these once-deadly infectious agents. However, a number of very serious health risks can still potentially exist in our water. The re-emergence of cholera and typhoid fever as health threats following the break up of the Soviet Union illustrates how health gains can easily be lost if water systems are not adequately maintained. A further example is an epidemic of cholera that swept through Peru, affecting more than 800,000 people, when chlorination was discontinued because of the fear of the effects of disinfection by-products. (Putnam & Wiener, 1995; Gribble, 1996).

Acute and Chronic Health Effects and Concerns

Waterborne contaminants can cause two types of health effects, acute and chronic. Aesthetic issues also cause health concerns.

Acute health effects arise immediately, within hours or days of ingesting the contaminant in drinking water. Microbial contaminants, such as bacteria, viruses, and protozoan parasites cause acute health effects, of which the symptoms are usually diarrhea, nausea and vomiting, and in extreme cases death. High levels of arsenic, nitrates, or other chemicals ingested through water can also cause acute, and sometimes fatal, illness.

Long-term health effects are the possible result of exposure to a drinking water contaminant day after day for many years at levels above the recommended guidelines. Contaminants that may cause cancer or other health effects after long-term exposure are usually elements, chemicals, or heavy metals in the water such as arsenic, lead, solvents, or disinfection by-products.

A third class of concerns are aesthetic concerns—contaminants that may make drinking water unpalatable or unattractive but do not cause health effects.

This chapter outlines the key acute and chronic health risks that may arise from drinking water in B.C. as well as aesthetic concerns. As much as possible, these risks have been ascertained from the best available medical evidence, scientific studies, and epidemiology. To adequately prevent adverse health effects from water consumption in B.C., it is essential that we understand the full range of bacteria, viruses, and parasites as well as chemicals and other contaminants that can enter into or exist in our water supply. Where the evidence is uncertain about whether a certain agent or chemical is harmful, we present the best available information. We then outline the best advice available for how to prevent the risk from occurring in the first place and how to minimize the risk if it enters the water supply. Further discussion of the methods of controlling the risks (risk management) can be found in Chapter 5.

Microbial Agents of Waterborne Disease

Water is a very hospitable medium for a number of micro-organisms—bacteria, viruses, and parasites—and provides an environment in which they can remain viable and be widely dispersed through the water system.

Microbes in drinking water have caused at least 29 outbreaks in B.C. over the last 20 years. Of those outbreaks, 17 (59 per cent) were caused by protozoan parasites that are more resistant to commonly used disinfectants such as chlorine.

▶ **See Table 1 page 14 for a list of the outbreaks in B.C. and the suspected organisms.**

Viruses, bacteria and parasites that can cause waterborne disease in humans share a number of common features. Most of them have animal hosts, usually mammals or birds, and can infect humans through eating contaminated meat, inadequate handwashing after direct contact with the animal, or through the environment, such as by drinking contaminated water. Some of the micro-organisms do not cause illness in the infected animals, and so apparently healthy animals can excrete micro-organisms that can cause infection in humans (Szewzyk, Szewzyk, Manz, & Schleifer, 2000). Human infection by these micro-organisms tends to most commonly appear as gastrointestinal illness—diarrhea, nausea, vomiting, and abdominal cramps. However, some can cause systemic disease, such as hepatitis (viruses), kidney failure (*E. coli* 0157:H7), and nerve and retinal damage (*Toxoplasma gondii*) (Krewski et al., 2001).

The probability and severity of the infection is dependent on a number of factors including, but not limited to, the size of the dose (the number of microbes ingested), the virulence of the microbe, and the susceptibility of the infected individual. In general, young children, the elderly or immune-compromised individuals, such as those with AIDS or those undergoing treatment for cancer, are much more at risk of serious illness and even death from waterborne disease.

Indicator Organisms

Total and Fecal Coliforms

For more than 100 years, the presence in water of any of a family of gram-negative, rod-shaped bacteria called total and fecal coliforms has been used as indicator organisms that the water is potentially unsafe. The coliform group consists of several genera (sub-groups) of bacteria including *Escherichia coli*, *Klebsiella*, *Enterobacter* and *Citrobacter*. Coliforms are a family of bacteria that exist in soil, water, and the intestinal tract of mammals. The name total coliform applies to the whole family. Fecal coliform applies to a subset that inhabits human and animal intestinal tracts and whose presence indicates contact with human sewage or animal manure.

Many of these bacteria are in themselves harmless and do not cause disease—they constitute the normal flora of the intestinal tract of humans and of other mammals. Their presence in the water, however, indicates that human sewage or animal feces may have entered the water supply. Since contamination by human or animal excrement presents the greatest danger to human health, testing for these organisms provides the most sensitive means for the detection of microbial pollution and potential problems. A positive test for fecal coliforms is a warning that microbiological contaminates may be present, such as the microbes that cause cholera, typhoid fever or hepatitis A, or the toxic strain of *E. coli* O157:H7. If total or fecal coliforms can be isolated from treated water, this is a clear indication that treatment has not been adequate or that contamination has entered the distribution system either through a cross-connection or through inadequate disinfection after construction or repair of the distribution system.

A positive fecal coliform count calls for immediate action by the health officials and re-sampling. In some cases it indicates the need for an immediate boil-water advisory. This is a judgement call that is made by health officials in consultation with the water supplier, considering the previous sample history, disinfection records, and the potential of contamination of the system.

Heterotrophic Bacteria

Another large and diverse group of bacteria is also used as an indicator organism for testing water quality. Called heterotrophic bacteria, they indicate the growth of biofilm—slimy growth—in the water distribution system. Although these bacteria have no direct relationship to fecal bacteria or to identifiable health risks, they do indicate the general microbiological content of the water and the levels of nutrients present in the water that can support bacterial growth. They are also characterized by their ability to grow on certain media in the laboratory (the number of bacteria is reported as the heterotrophic plate count). Their absence in a plate count test is an indicator of a lack of bacterial re-growth in the distribution system.

Testing water for the presence of these indicator bacteria is relatively easy and inexpensive to do. In recent years, however, there has been debate about the ultimate value of these surrogate tests, because water that may test free of fecal coliforms and heterotrophic bacteria could still be harbouring potentially dangerous agents, such as the parasites *Giardia* or *Cryptosporidium*. There has been debate whether the tests should focus more on the *E. coli* species of bacteria, since these are more precise indicators of fecal contamination. A new test, called a Defined Substrate Test, has been used for the simultaneous detection of *E. coli* and total coliforms in the same water sample. These tests can be used in the field as a Presence/Absence test in which a sample is taken and placed in contact with a reagent. The presence of fluorescence in the sample upon incubation indicates that *E. coli* are present. A similar test may be used in the laboratory to provide quantitative measures. A number of countries have already adopted *E. coli* testing as an alternative to fecal coliform testing, including the U.S.A, European Community members, and New Zealand (J. Fung, personal communication, March 7, 2001). *E.Coli* as a standard has been included in the current revision of B.C.'s Safe Drinking Water Regulation.

[illegible]

Heavy rains during the week of May 17, 2000 washed cattle manure into a shallow well on a farmer's field. The manure carried *E.coli* 0157:H7 as well as *Campylobacter* which then contaminated the town's aquifer.

On May 20, the first patients began complaining of severe, bloody diarrhea. By May 22, 1,353 patients had been identified as carrying the bacteria. An estimated 2,700 people in total were infected, of whom 65 were hospitalized and 27 went on to develop hemolytic uremic syndrome (HUS). Seven people died. Those who survived HUS are now taking daily medication (ACE inhibitors) in the hope the drug will reduce their chance of developing permanent kidney damage.

A prospective study is now underway to follow the most seriously affected survivors of the outbreak in future years to better understand the full impact of infection with *E.coli* 0157:H7 (Dr. H. Lynn, personal communication, February 14, 2001).

Disease-causing (Pathogenic) Bacteria

Enterohemorrhagic *E. coli*

There are more than 50 different strains of the Gram-negative, rod-shaped bacteria *E. coli*, (B. Finlay, personal communication, January 20, 2001), and most of them are harmless. Some strains cause human illness (diarrhea, vomiting and fever) by invading the bowel or producing a toxin.

A particularly virulent group, known interchangeably as enterohemorrhagic *E. coli* (EHEC) or verotoxigenic *E. coli* (VTEC), can cause severe illness and serious complications. One of the more common EHEC strains is *E. coli* O157:H7, which emerged for the first time 20 years ago and has now become a major public health threat around the world (Szewzyk, Szewzyk, Manz, & Schleifer, 2000). It can cause severe bloody diarrhea, and in some cases kidney failure and potential death from hemolytic uremic syndrome. Carried harmlessly in the gut of cattle, it can enter into the water supply when cattle manure contaminates the source water. There is increasing evidence that deer in North America may also carry the organism (Chin, 2000). Other avenues of infection include raw or undercooked hamburger, unpasteurized milk and juice, unwashed fruits and vegetables that have been fertilized with infected cow manure, and poor hand washing. It takes an extremely small dose—less than 10 bacteria—to cause infection, which incubates from two to eight days before causing disease (B. Finlay, personal communication, January 20, 2001). Diarrhea may range from mild and non-bloody to stools that are virtually all blood. In two to seven per cent of infected individuals, particularly the elderly and children under five, the infection progresses to hemolytic uremic syndrome, which is characterized by acute kidney failure and the risk of death.

At the present time, there is no effective medical treatment other than supporting the individual with fluid and electrolyte replacement, and, in the case of hemolytic uremic syndrome, dialysis, until kidney function returns (Chin, 2000). Unlike the outbreak in Walkerton, Ontario there have been no recorded waterborne outbreaks of *E. coli* O157:H7 yet in B.C., but we have had cases linked to undercooked hamburger, unpasteurized apple juice and tainted salami.

Prevention for Enterohaemorrhagic E. coli:

- **Avoid fecal contamination of water supply. Prevent cattle or deer grazing in or near water source.**
- **Provide adequate disinfection (chlorination, ozonation, or ultraviolet radiation) or adequate filtration plus disinfection.**
- **Boiling water also kills the organism.**

Campylobacter

There are more than 20 different strains of the Gram-negative bacteria *Campylobacter* that may be carried by many animals including puppies, kittens, chickens, pigs, wildlife and cattle. The microbe is thought to be responsible for five to 14 per cent of all cases of diarrhea worldwide (Chin, 2000). The bacteria enter water usually through fecal contamination of the water supply. Other modes of transmission include eating undercooked meat, cross-contamination from cutting boards and cooking implements, as well as poor hand washing after handling infected animals or meat. The resulting human illness, campylobacteriosis, is characterized by diarrhea, abdominal pain, malaise, fever, nausea, and vomiting. Symptoms usually last two to five days, but recurrences are possible. *Campylobacter* infections can be more serious to small infants, the elderly, and immune-compromised adults.

Campylobacter in B.C.

At least four waterborne outbreaks of *Campylobacter* illness have occurred in British Columbia in the last 10 years.

In 1998, the surface water supply at a summer camp for children on the Sunshine Coast became contaminated with Campylobacter. The bacteria probably entered the water from contamination by feces of infected wildlife. The camp was not adequately chlorinating the water, and a number of the children developed severe diarrhea. Rather than chlorinate, the camp switched to bottled water.

A rare condition that has been associated with *Campylobacter* infection is called Guillain-Barre syndrome (GBS). This neurological syndrome, in which the immune system attacks the myelin sheath around peripheral nerves, has been shown to occur in one or two of every 2,000 cases of *Campylobacter* infection. There are about 80 GBS cases a year in B.C. According to studies, about 30 per cent would be thought to have *Campylobacter* infection as the precursor (Bolton, 1995). Symptoms of progressive numbness, muscle weakness, and paralysis typically develop two to three weeks after infection. The syndrome leads to paralysis of the arms and legs that can progress to respiratory muscle paralysis over two to three weeks. Recovery can take weeks to months, with a minority of people having permanent effects of the paralysis. Death from GBS can also occur. GBS following *Campylobacter* infection tends to be more severe than GBS that occurs without prior infection (Rees, Soudain, Gregson, & Hughes, 1995).

Prevention for Campylobacter:

- **Avoid having animal feces where it can wash into the water supply.**
- **Provide adequate disinfection (chlorination, ozonation or ultraviolet radiation) or adequate filtration and secondary disinfection.**
- **Boiling water also kills the organism.**

Cyanobacteria

More commonly known as "blue-green" algae or "pond scum," cyanobacteria are single cell organisms that form in shallow, warm, slow moving, or still water. In hot summer months in Canada, cyanobacteria "blooms" can develop in water supplies, particularly in water that is nutrient-rich, such as water high in phosphates. The risk to human health is that some strains carry toxins that are released when the algae cells rupture or die. Cyanobacteria potentially carry toxins that attack the liver (hepatotoxins), the nervous system (neurotoxins) or simply irritate the skin (Health Canada, March 24, 1998). The hepatotoxins are one of the greatest concern because even after the cyanobacteria die, the toxins can remain in the water for long periods of time.

Few incidents of human poisoning by cyanobacteria have been reported—people aren't apt to drink water contaminated with cyanobacteria because fresh blooms smell like newly mown grass, and older blooms smell like rotting garbage. But people can be exposed after swimming in contaminated water or drinking water containing toxins in which the algae bloom has already died. If water is contaminated by cyanobacteria, you should not drink it, bathe in it, cook with it, nor wash clothing or dishes in it.

Prevention for Cyanobacteria:

- **Limit the input of nutrients, such as phosphates and fertilizers, into water supplies.**
- **Surface water, particularly shallow reservoirs, should be mixed and kept moving, not allowed to heat up and sit still.**
- **Treatment to remove cyanobacteria is usually by adding chemical to coagulate and precipitate the organism.**
- **Boiling water is not effective. In fact, boiling concentrates the toxins.**

Other Pathogenic Bacteria

A number of other bacteria that can cause disease in humans can be spread through the water supply. These include strains of *Salmonella*, including *S. typhi* and *S. paratyphi* (the agents responsible for typhoid fever and paratyphoid fever), *Vibrio cholera* (the agent responsible for cholera), *Yersinia*, and *Shigella*. These bacteria can cause mild to severe gastrointestinal illness and potentially fatal complications. In the last 20 years in B.C., there have been two recorded waterborne outbreaks caused by Salmonella. These bacteria can pose a health threat through inadequate disinfection or if, like *E.coli* O157:H7, one of the strains develops new virulence factors through mutation or incorporation of new DNA from other bacteria (Szewzyk, Szewzyk, Manz, & Schleifer, 2000).

Another bacterium that is emerging as a potential pathogen transmitted through water is *Helicobacter pylori*, the agent now associated with stomach ulcers, stomach cancer, and infection of the stomach lining (Chin, 2000).

Prevention for other pathogenic bacteria:

- **Avoid human and animal fecal contamination of the water supply.**
- **Provide adequate disinfection (chlorination, ozonation or ultraviolet radiation) or adequate filtration plus secondary disinfection.**
- **Boiling water also kills these organisms.**

Viral Agents

Viruses, at less than 0.3 microns, are the smallest microbes to contaminate the water supply. They tend to be hardier and persist in the water longer than bacteria. However, if there is no human fecal contamination of the water supply, there is little chance of the virus being introduced into the water.

A number of viruses have been identified that cause gasteroenteritis—diarrhea, vomiting, and malaise—which may be spread through contaminated water as one of the modes of transmission. These viral agents include hepatitis A and E, rotaviruses, which cause diarrhea in infants and immune-compromised adults, and the Norwalk-like viruses, which infect healthy adults and children and may cause such symptoms as diarrhea, nausea, vomiting, malaise, or fever, or a combination of those symptoms for 24 to 48 hours. While difficult to culture or isolate from water, there is increasing belief that viral gasteroenteritis may be commonly spread through inadequately treated water as one of its transmission routes (Chin, 2000).

Prevention for viral agents:

- **Avoid human and animal fecal contamination of the water supply.**
- **Provide adequate disinfection (chlorination, ozonation or ultraviolet radiation) or adequate filtration plus secondary disinfection.**
- **Boiling water also kills the organism.**

Parasites

Giardia

Flagellate protozoa, *Giardia lamblia*, is a parasite carried by humans and wild and domesticated animals. It is found throughout rural and wilderness areas of B.C. The infection, giardiasis, has been given the colloquial (and inaccurate) name of "beaver fever." The parasite infects the intestinal tract of warm-blooded animals and is excreted in feces. Part of its lifecycle includes the formation of a durable cyst that may remain viable for many months. Cysts can contaminate surface water through animals or humans defecating directly in the water or when excessive runoff sends contaminated soil into the surface water source. Other sources of infection can include inadequately chlorinated swimming pools, person to person transmission for example in daycare settings, and improper food handling by an infected individual. After ingestion of the cysts, humans incubate the parasite from three to 25 days, with seven to 10 days being the average (Chin, 2000). Symptoms of infection include chronic diarrhea, steatorrhea (the presence of fat in feces), abdominal cramping, bloating, frequent pale greasy stools, fatigue and weight loss. Reactive arthritis may occur and, in severe giardiasis, damage to the intestine may occur. The infection may clear without treatment, but treatment with an anti-microbial medicine such as metronidiazole (Flagyl) is recommended.

[illegible]

In the last 20 years, there have been 13 confirmed waterborne outbreaks of giardiasis in British Columbia. In a 1995 outbreak in Revelstoke, laboratory tests confirmed 71 cases of campylobacteriosis, 62 cases of giardiasis, 9 cases of yersiniosis and 4 of cryptosporidiosis. The estimate is that perhaps hundreds more experienced diarrhea and gastroenteritis without having the agent confirmed by laboratory tests (Dr. M. Fyfe, personal communication, February 14, 2001).

A beaver had built its lodge right near the intake pipe of the town's water supply. It is believed that this animal was the source of the microbes. The town did not filter nor disinfect its water. Revelstoke has since built B.C.'s first membrane filtration plant.

Testing for *Giardia* in water is difficult and often unreliable. There is a lack of standardized analytical methods with which to interpret the results. Standard testing processes cannot differentiate cysts that are alive or dead—infectious or non-infectious. Non-viable, non-infectious cysts may turn up in monitoring results but bear no relation to human illness. In addition to being unreliable, monitoring for *Giardia* is expensive.

Prevention for Giardia:

- **Avoid animal grazing near water source.**
- **Limit wildlife corridors near water source.**
- **Avoid excessive runoff into water source.**
- **Remove beaver from watersheds.**
- **Chlorine alone can be effective in killing the cysts if there is adequate contact time; this is difficult to achieve for some large volume water systems. Multiple disinfectants, such as ozone and chlorine combined, can kill *Giardia*. (The benchmark is filtration followed by chlorination.)**

- **Cyst removal can be accomplished by filtration that removes all particles one micron or greater.**
- **Ultraviolet radiation may emerge as proven treatment in the future.**
- **Boiling water for at least one minute also kills the cysts.**

Cryptosporidium

Cryptosporidium is a protozoan parasite, and its strains have been found in more than 80 animal species, particularly young cattle and other young domesticated animals. The species that is believed to cause most of the infections in humans is *Cryptosporidium* parvum. The parasite lives in the intestinal tract and forms durable forms called oocysts. The oocysts can remain viable in soil and water for two to six months (Chin, 2000). Oocysts can be introduced into the drinking water supply through animals defecating in the water source or through runoff that washes contaminated soil into the water source. Other sources of infection are through the exposure to feces of an infected individual or infected animals, such as through contaminated produce or unpasteurized juice.

Cryp[illegible] B.C.

There have been at least three confirmed outbreaks of cryptosporidiosis in B.C. since 1995. The largest outbreak was in 1996 in Kelowna. During the summer, numerous people developed diarrhea, and 177 cases of cryptosporidiosis were confirmed by laboratory tests. It is estimated that about 10,000 residents were infected, some from the water and others from contact with infected individuals.

A boil-water advisory was put in place for August while public health officials searched for the source of contamination. Since Kelowna draws its water from Okanagan Lake, it was assumed the source was manure run-off from infected cattle on nearby agricultural land. But two years later, scientists working on the genetic typing of the organism discovered it was a human strain, which points to contamination by human sewage or another human source. There is uncertainty about the original source of this contamination.

Up until 10 years ago, *Cryptosporidium* was not considered a serious agent of waterborne disease for humans, although the infection was well recognized in animals. A waterborne outbreak in Georgia, however, affected an estimated 13,000 people. Then in 1993, an estimated 400,000 people were infected in Milwaukee, and an estimated 70 people died when the municipal water supply became contaminated (MacKenzie et al., 1994; Hoxie, Davis, Vergeront, Nashold, & Blair, 1997). It is now believed that *Cryptosporidium* can contaminate any water supply that is subject to runoff that may carry wild or domestic animal waste or be contaminated with human sewage from infected individuals. One infected calf can shed up to 10 million oocysts a day (Rose, 1997). There have been significant outbreaks of waterborne *Cryptosporidium* infections in British Columbia in Kelowna and Cranbrook (1996) and in Chilliwack (1998). In May 2001 an outbreak of waterborne *Cryptosporidium* in North Battleford, Saskatchewan received widespread national media coverage.

Recent studies by several research groups around the world have found that there are two major genotypes, or strains, of *C. parvum* (the main species of *Cryptosporidium*) that cause infection in humans: human genotype and calf genotype (Peng et al., 1997; Ong et al., 1999; Awad-El-Kariem, 1999; McLauchlin, Amar, Pedraza-Diaz, & Nicholas, 2000). At present, it is universally accepted that if humans in an outbreak are infected with the human genotype, the contaminating oocysts are most likely from a human source, such as sewage (C. Ong, personal communication, March 27, 2001). In contrast, the calf genotype has been isolated from both humans and calves as well as other livestock and wild animals such as sheep, goats and deer (Ong et al., 1999).

Secondary spread of the calf genotype can occur from human to human (Millard et al., 1994). Other genotypes of C. *parvum* include dog, bear, mouse, and koala strains, but only a few cases have been reported in immuno-compromised humans There have also been a few reports of other *Cryptosporidium* species (e.g. C. *felis* , from cats) infecting immuno-compromised individuals. (Pieniazek et al., 1999).

The number of oocysts that need to be ingested to cause infection is not clear (Chin, 2000). Less virulent strains may require thousands of oocysts to cause infection in humans. With a highly virulent strain, infection may result from ingestion of a single oocyst (Parlange, 1999). The most common symptoms of infection are watery diarrhea, abdominal cramps, nausea, vomiting, fever, headache and loss of appetite, but some people can carry the parasite without any symptoms. There is no effective treatment for cryptosporidosis. Healthy adults usually clear the infection within two weeks, but young children, the elderly and people with weakened immune systems, particularly people with HIV, AIDS, cancer or recent organ transplants can have more severe and long lasting infections that may even contribute to death. The parasite is endemic in B.C., and there have been three confirmed waterborne outbreaks of cryptosporidiosis in the last five years.

Immuno-compromised individuals are advised not to drink water directly from lakes, rivers and streams in B.C., to strictly follow boil-water advisories, and to consider further treatment of their water, such as routine boiling or purchasing water that has been microfiltered or treated by reverse osmosis. The Provincial Health Officer issued a public advisory in 1996 and re-issued it in 2001.

▶ See Appendix B for Office of the Provincial Health Officer web site.

Like *Giardia*, testing for *Cryptosporidium* in water is difficult and often unreliable. There is a lack of standardized analytical methods with which to interpret the results. Standard testing processes cannot differentiate between oocyst strains that infect humans and those that only infect animals. It cannot determine whether the *Cryptosporidium* oocysts are alive or dead—infectious or non-infectious (similar to *Giardia* cysts). Non-viable, non-infectious oocysts may turn up in monitoring results but bear no relation to human illness. A new test, using reverse-transcriptase PCR (RT-PCR) has been described for *Cryptosporidium* which may improve testing capabilities, however, this test is not yet sufficiently developed to be available for routine sampling of water supplies (Kauchner & Stinear, 1998). In addition to being unreliable, monitoring for *Cryptosporidium* is expensive.

When a sufficient number of samples are collected, it is possible to establish a range of oocysts present in the supply and their relationship to seasonal variations, rainfall events, and differences in agricultural activity levels. Once these relationships have been established, it is then possible to vary treatment processes accordingly. Land use activity and the habitat's desirability for wildlife are two of the most important elements used to define a watershed's vulnerability to *Cryptosporidium* loading. There is a correlation between turbidity—the murkiness or cloudiness of water—and the amount of microorganisms in the water. In the future, turbidity levels or the more sensitive particle counts may emerge as a way to better predict the risk of waterborne illness from *Cryptosporidium.*

▶ **See also page 59 Turbidity.**

Cryptosporidium is a very resistant protozoa that requires a multi-barrier approach. There is no quick or simple fix to remove *Cryptosporidium* from water.

Prevention for *Cryptosporidum*:

- **Avoid animal grazing near the water supply.**
- **Limit wildlife corridors near the water supply.**
- **Avoid excessive water runoff into the water supply.**
- **Chlorine alone is not effective in inactivating the oocysts. Ozone can be effective, but only at extremely high doses.**
- **Filtration and multiple disinfectants are more effective at inactivating oocysts than a single process. Microfiltration and reverse osmosis technologies that remove all particles one micron or greater, remove the oocyst.**
- **UV radiation is a promising technology that is being evaluated for its effectiveness in the inactivation of oocysts. Published results for UV inactivation of cryptosporidium in water in peer-reviewed literature may be one to two years away.**
- **Boiling water kills the oocysts.**

Toxoplasma gondii

Another protozoan parasite, *Toxoplasma gondii*, infects birds, mammals and humans, but it only reproduces in the intestines of domestic and wild cats. During reproduction it produces very durable oocysts that can remain viable in soil for more than a year. One infected cat can shed 200 million oocysts (Dubey & Beattie, 1988). It is most commonly spread to humans by ingesting the oocysts after coming into contact with cat feces, such as changing litter boxes or gardening. Infection can also occur after eating meat from infected animals in which the parasite has encysted.

Toxoplasma is not widely recognized as being a common waterborne agent, but an outbreak in 1995 in Victoria has been linked to two periods of heavy rainfall in which soil was swept into a shallow reservoir serving the city (Bowie et al., 1997). There are no routine tests yet to isolate or identify *Toxoplasma* oocysts in water (Isaac-Renton et al., 1998).

Symptoms of the infection, called toxoplasmosis, are swollen lymph glands (lymphadenopathy) and sometimes flu-like symptoms with fever and malaise. Some people who are infected show no symptoms at all. The parasite can migrate through tissue in the body, and lodge for example in the brain, in the retina of the eye (causing eye damage) and in the heart (causing inflammation of the heart muscle.) The parasite can remain dormant in the body for years and reactivate if the infected individual's immune system becomes suppressed. It is particularly dangerous to individuals with HIV or AIDS and to the developing fetus.

[illegible]

In March of 1995, a sudden increase in the number of positive *Toxoplasma gondii* laboratory tests coming out of the Victoria region alerted medical microbiologists at the B.C. Centre for Disease Control of a potential outbreak. Concurrently, two Victoria eye specialists diagnosed seven cases of acute Toxoplasma retinitis, the first such incidents they had seen in more than five years.

A screening program of some 3,800 pregnant and newly-delivered women in the region was conducted. In total 37 pregnant women, 13 infants and 63 symptomatic individuals were confirmed with infection. The infants received extensive treatment, and while no serious complications have yet been seen, six had eye involvement, three of those in both eyes. None of the babies are legally blind (Dr. A. Burnett, personal communication, March 5, 2001). Of the identified adults infected, 20 have retinal damage, and five people have lost vision in one eye.

"This parasite has the potential to reactivate at any time in the future and cause more retinal damage in adults and children alike. Therefore, the final visual outcome remains an uncertainty," said Dr. Andrew Burnett, one of the ophthalmologists who discovered the first cases and is now following the infected individuals.

Detailed epidemiological studies of the outbreak revealed that the individuals lived or worked in a region of the city served by water from the Humpback Reservoir, now closed. The outbreak was associated with two periods of heavy rainfall and increased turbidity in the water supply (Bowie et al., 1997).

Inadequate disinfection of Victoria's water supply may have contributed to the outbreak. The outbreaks occurred after logging had been stopped in the watershed. A number of feral cats present around the Humpback reservoir were likely the source of the outbreak.

An infant infected in utero can develop severe brain damage, eye damage, convulsions, liver damage, and other serious complications. Toxoplasmosis can even lead to stillbirth and perinatal death. Fortunately, prompt and effective treatment of the infected infants in the Victoria outbreak prevented these complications from occurring (Bowie et al., 1997; Burnett et al., 1998; Aramini, Stephen, & Dubey, 1998; Aramini et al., 1999).

Prevention for Toxoplasma:

- **Limit or remove cat populations, including domestic cats and cougars, from land surrounding reservoirs.**
- **It is not clear whether disinfection with chlorine, ozone or UV radiation adequately kills the oocysts.**
- **Microfiltration is an effective way to remove the cysts.**
- **Boiling water is also believed to kill the oocysts.**

Other Parasites

There are a few other parasites that are emerging as potentially waterborne, although their significance in B.C. is not yet known.

Cyclospora cayetanesis is a protozoa that was originally thought to be one of the family of blue-green algae. It produces oocysts similar in appearance to *Cryptosporidium*. It causes watery diarrhea and cramping. Outbreaks have been associated with drinking or swimming in water contaminated with animal or human feces and with eating contaminated produce.

Another parasite, *Entamoeba histolytica* is most common in developing countries or areas of close quarters and poor sanitation. Many infections occur without symptoms; it can however, cause fever, chills and bloody or mucoid diarrhea. It is common to travellers in Asia and South America.

Prevention for other parasites:

- **Avoid animal and human fecal contamination of water.**
- **Provide adequate filtration plus disinfection.**
- **Boiling water will kill the organisms.**

Physical Parameters

Turbidity

Turbidity is a measure of the relative clarity of water. It is usually measured in nephelometric turbidity units (NTU). Clear water has a low NTU value, and cloudy or murky water has higher NTU values. Turbidity is caused by suspended organic and inorganic matter, soluble coloured compounds, and microscopic organisms. It is not a direct measure of suspended particles in water, but a measure of the scattering effect this matter has on light.

Turbidity in Kamloops

Every so often, the municipal water system in Kamloops is subject to times of high turbidity, up to 500 NTU. The source is probably increased silt and debris in the South Thompson River, which feeds the town's water intake.

The local medical health officer conducted a study and found that visits to local physicians for gastrointestinal complaints were associated with increases in water turbidity.

Now, the city has an automatic water quality advisory in times of high turbidity, and the local media routinely reports turbidity levels. Under an order issued pursuant to the *Health Act*, as well as conditions placed on the operating permit pursuant to the Safe Drinking Water Regulation, the municipality is developing a plan to improve water quality. Many Kamloops residents have purified water brought into their homes (J. Lu, personal communication, February 20, 2001; K. Christian, personal communication, March 26, 2001).

Since instituting turbidity advisories along with streamside protection measures in the watershed, physician office visits for intestinal illnesses have decreased by 19 per cent (Population Health Surveillance and Epidemiology, July, 2001).

It is also possible to count the number of particles of a certain size in water. This will measure many, but not all, of the material in water that can affect the turbidity measured in NTUs. As particle counts increase in water, the turbidity measured in NTUs also increases. However, because they measure slightly different things, there is no precise relationship between these two measures.

Turbidity is known to increase during periods of snow melt or heavy rainfall, when increased surface run-off flows into the water source or when increased activities in the watershed, such as landslides, logging or construction, may introduce soil into the water source.

Extreme precipitation has been shown to be associated with waterborne disease outbreaks in the United States (Curriero et al., 2001).

As many different types of matter in water can affect turbidity measurements, it has no direct relationship to health risk. Turbidity can, however, provide a useful indirect indicator of risk.

There are several ways in which turbidity may reflect a health risk. Turbidity may increase when sand, silt, and other small soil particles are carried into a body of water. Along with these soil particles, harmful microscopic organisms such as *Cryptosporidium* and *Giardia* may be carried into the water. These microscopic organisms can infect people who drink the water unless the water is adequately disinfected and/or filtered.

Turbidity has been shown to be correlated with contamination with bacterial contaminants, *Giardia*, *Cryptosporidium* and may serve as a surrogate measure for risk of contamination by waterborne pathogens. However, turbidity cannot by itself be used to predict the occurrence of waterborne pathogens. Waterborne pathogens may be present in high turbidity waters, but they may also be present in low turbidity waters.

Turbidity can reduce the effectiveness of disinfectants such as chlorine, ozone, or UV light. Microscopic organisms that are attached to, or hiding among, particles in the water may be less sensitive to the disinfectant. Relatively more of them may survive the disinfection process and infect people drinking the water.

Some types of organic matter included in measures of turbidity may react with chlorine and produce by-products such as trihalomethanes (THMs). If ozone is used as a disinfectant, the by-products formed may provide a better source of food for microscopic organisms to re-grow in water distribution pipes.

▶ **See disinfection by-products page 69 and THMs page 70.**

Studies in British Columbia, particularly a recent comprehensive study in the Greater Vancouver Water District, have shown a relationship between turbidity measured in NTUs and gastrointestinal illness (Aramini et al., 2000). It is not clear whether this relationship is due to larger numbers of harmful microscopic organisms, such as *Cryptosporidium* or *Giardia*, being present in water with higher turbidity or to some other factor. Based on current knowledge, it is not possible to define a precise relationship between turbidity and health risk. There is evidence that as turbidity increases, the risk of gastro-intestinal illness increases, and that this relationship is present even at relatively low levels (1 NTU). A report has been prepared for the Simon Fraser Health Region in cooperation with other health regions served by the Greater Vancouver Water District supply system on the public health considerations related to turbidity in drinking water sources. The report will assist the medical health officers in discussions with the water supplier as to when health advisories may be given or modifications to the water system made to minimize turbidity (Economic and Engineering Services, Inc., 2001).

Based on health considerations, Health Canada has set a Canadian Drinking Water Guideline for turbidity of 1 NTU for water entering a distribution system. A less stringent value of 5 NTU may be permitted for water with a history of acceptable microbiological quality, if disinfection will not be compromised.

Chemical Contaminants

Adverse health affects from drinking water are not only associated with microbes. As water travels, either above or below the ground, it can pick up chemicals such as heavy metals, nitrates, pesticides, gasoline, and radioactive metals. Some of these substances get into drinking water as a result of human activities, while others are naturally occurring.

Arsenic

Arsenic is widely distributed throughout the earth's crust and may be found in water that exposed to arsenic-rich rocks. Arsenic is also frequently used as an industrial alloy or is a by-product in the manufacturing of many products. It can be introduced into the drinking water through the leaching of the arsenic from bedrock sources into aquifers, wells, and surface water, from the use of arsenic-containing pesticides, or from the settling on water of atmospheric pollution containing arsenic. According to the

Guidelines for Canadian Drinking Water Quality, the interim maximum acceptable concentration for arsenic in water is 25 micrograms per litre.

In 1993, the World Health Organization changed its suggested guideline value for arsenic in water from 50 micrograms per litre to a provisional 10 micrograms per litre. A number of countries adopted the provisional guideline of 10 micrograms per litre as the standard, although many countries kept the earlier guideline as their national standard. (World Health Organization, 2001). The U. S. Environmental Protection Agency reduced its maximum contaminant level for arsenic to 10 micrograms per litre in January 2001, but has since suspended the implementation to allow for further scientific and public input (U.S. National Archives and Records Administration, 2001).

Arsenic in the Sunshine Coast

In April 1993, a family living near Powell River had their well water tested when family members failed to recover from an extended illness. The water tests revealed arsenic levels 13 times higher than the level recommended by Health Canada. Subsequent testing throughout the region found a significant number of wells had levels exceeding the maximum acceptable concentration set by the *Guidelines for Canadian Drinking Water Quality*.

In total, 25 out of 199 wells tested in Powell River and 61 out of 259 wells tested in the Sunshine Coast exceeded 25 micrograms/L.

Municipal water in the region is fine, but private wells serving individual households or small subdivisions may have a problem. Currently, the Coast Garibaldi Health Region recommends that home owners with affected wells buy a treatment system either to be placed at the tap (point of use) or where the water main enters the house. Residents should not drink or cook with water on a regular basis that has arsenic exceeding 25 micrograms/L (Carmichael, 1995).

Humans routinely consume arsenic derivatives in many forms—in meat, vegetables, and particularly seafood. Average daily consumption in Canada is estimated to be about 16.7 micrograms. In general, a larger proportion of a person's arsenic intake is derived from food sources, which contain mostly organic arsenic. The inorganic type of arsenic is the most toxic, and this is the type that is found in water.

One of the problems with arsenic concentrations is that there is no clear consensus on what the dose-response and dose-effect relationships are to human health. It is thought that humans need some exposure to arsenic to survive. According the fact sheet *Arsenic in Drinking Water* published by the World Health Organization, the signs and symptoms that arsenic causes appear to differ between individuals, population groups, and regions. Thus, there is no universal definition of the health effects caused by arsenic (World Health Organization, May 2001).

It is not clear exactly how much arsenic is required to create adverse health effects over the long term. The main health issue has been shown to be hyperkeratosis (a thickening of the skin) and pigmentation as well as other skin lesions and warts after a five-year exposure period. Skin cancer has been shown to occur after prolonged ingestion of arsenic (25 years). Increased rates of vascular disease, other cancers, and peripheral neuropathy (numbness in extremities) have also been associated with prolonged exposure. Acute arsenic intoxication associated with the consumption of well water containing arsenic at 1.2 and 21.0 mg/L have been reported. Symptoms of acute arsenic poisoning can include abdominal pain, vomiting, diarrhea, headache, fever, convulsions, and abnormal heart rhythm.

Arsenic is of particular interest in B.C. because some communities have groundwater sources that are exposed to arsenic-bearing rocks. Some wells in the Sunshine Coast area have arsenic levels that are above the recommended level in the *Guidelines for Canadian Drinking Water Quality*. There are scattered occurrences of arsenic exceeding guidelines in the Interior, and other, less frequent occurrences of elevated arsenic in the Gulf Islands, Vancouver Island, Lower Fraser Valley, and Rocky Mountains regions (Cui & Wei, 2000). Interpreting the significance requires a site-specific risk assessment for a particular water supply, followed by public health interpretation and then either a public advisory or some form of treatment.

Arsenic can be reduced in water to low levels through various treatment methods. A number of in-home water treatment devices—such as reverse osmosis, water distillers, mixed-bed deionizers, and activated alumina filtration—are available to reduce arsenic levels at the tap. These types of devices are called point-of-use treatments.

The advantage of point-of-use systems are that they are relatively inexpensive, but the disadvantage is that some taps—such as an outdoor faucet—will be untreated, leading to the chance that the water could be consumed. Since impact of arsenic consumption is cumulative, the occasional ingestion of water from an untreated tap is not a health concern. Other treatment methods can be placed where the water main enters the house (called point-of-entry treatment). These are more expensive but they do ensure that all water entering the house is suitable for drinking. Health Canada does not regulate home treatment and filtration systems, so home owners should research their purchase carefully.

Inexpensive and practical solutions to remove arsenic are being developed, particularly to deal with arsenic problems in poor, developing nations, such as Bangladesh. Numerous companies and university engineering departments around the world have been working on effective and inexpensive arsenic removal systems, which are expected to soon become available.

Prevention for arsenic contamination:

- **Test all well sources for arsenic prior to initial use.**
- **When there is identified increased arsenic concentrations in water supplies decrease the concentration by a point-of-entry treatment device.**

Nitrates and Nitrites

Nitrate (NO_3) and nitrite (NO_2) are products of the oxidation of nitrogen and are everywhere in the environment. Nitrate is more stable than nitrite, and both easily dissolve in water. Most nitrogenous material in the environment tends to convert to nitrate. Sources of nitrates in water include agricultural fertilizers, explosives used in mining or construction, animal manure, human sewage, decomposing plant and animal matter or geological formations containing soluble nitrogen compounds. While nitrates can occur naturally in water, most elevated nitrate concentrations in drinking water supplies come from human activities, particularly farming. Nitrate-nitrogen levels of 3 mgL or higher are an indication of influence from human activity (Health Canada, 1987, Nitrate/nitrite).

[illegible]

A large aquifer in the Fraser Valley near Abbotsford has been shown to contain levels of nitrate that are just above the maximum level recommended in the *Guidelines for Canadian Drinking Water Quality*. This aquifer does not supply the municipal system, except during times of the year when Norrish Creek has high turbidity. The aquifer serves, via private wells, a few hundred different households, as well as serving the Clearbrook Water Works system.

Test wells are sampled twice a year, and residents are informed of the significance of test results and what do about it. No adverse health affects have been reported.

The Abbotsford Aquifer Users Committee has sent out a notice to all addresses over the aquifer that says, "You are sitting on your drinking water, don't contaminate it!"

Nitrates resulting from agricultural activity near well heads or where surface water can enter aquifers are also a potential problem in the Grand Forks region, Osoyoos, Vernon, Fort St. John, Smithers, and Williams Lake.

Under Health Canada's *Guidelines for Canadian Drinking Water Quality*, the maximum acceptable concentration for nitrate in drinking water is 45 mg/L (10 mg/L when expressed as Nitrate-Nitrogen). Nitrate-Nitrogen concentrations in groundwater are typically less than 10 mg/L, but this guideline can be exceeded, particularly in well water. Nitrates enter the water supply when a well is not adequately sealed from runoff or the ground above an aquifer is porous. Shallow wells are more susceptible to contamination by nitrates than deep wells. During periods of heavy rain, nitrate-rich water can seep down through the soil into unconfined aquifers, particularly if the ground above is saturated with fertilizer. Some aquifers are more vulnerable to contamination as a result of their hydrogeology—particularly where there is considerable recharge of the groundwater from surface water supplies, for example, agricultural land run-off. In most cases, bacteria can enhance production of nitrate from nitrogen thus, worsening its effect on human health (National Research Council, 1995). Vegetables that have been irrigated with high-nitrate water will also be high in nitrates.

Excessive nitrate consumption through contaminated drinking water or food can harm human health by changing the oxygen-carrying hemoglobin in red blood cells to methemoglobin, which doesn't carry oxygen well. Low concentrations of methemoglobin are not a concern, as people normally have 0.3 per cent (non-smokers) to 1.3 per cent (smokers) in their blood stream. Higher levels, however, can cause cyanosis (insufficient oxygenation of the blood) characterized by bluish skin and lips and can eventually lead to death. At five to 10 per cent methemoglobin, the skin begins to turn grey. At 40 per cent, adults will have a headache and be short of breath. Levels over 70 per cent cause death.

Ingestion of nitrates in water is of particular concern for infants, especially those under six months of age who are not breastfed. Studies (that include dose information) have reported nitrate-induced problems in non-breastfed infants occurring at nitrate concentrations greater than 50 mg/L (equivalent to >10 mg/L Nitrogen). Other people who are more vulnerable to nitrates' effects are those with diarrhea or who are taking stomach-acid suppressing medication, people on dialysis, those with Vitamin C deficiency, those with an enzyme deficiency called Glucose-6-phosphatase dehydrogenase deficiency, and those with a hereditary disposition to methemoglobinemia (particularly some Native American tribes). There are some studies that suggest long-term exposure to elevated nitrate levels in water may cause gastric cancer, lymphoma, thyroid disorder, and birth defects, but these studies are not considered definitive (Schubert, Kanarek, Knobeloch, & Anderson, 1999).

Prevention for nitrate contamination:

- **Shallow wells, particularly on farms, are at greatest risk for contamination. Public water supplies and private wells in high risk areas should be tested at least once.**
- **Reverse osmosis and distillation removes nitrates, however boiling water makes nitrate levels higher.**
- **Infants must not be fed formula made from water with elevated nitrate levels.**

Lead

Although naturally-occurring lead in bedrock can dissolve into water supplies, most elevated lead levels in drinking water comes from the pipes or soldering of pipes in homes built prior to 1945. Under the *Guidelines for Canadian Drinking Water Quality*, the maximum acceptable concentration for lead is 0.010 mg/L. Elevated lead levels in drinking water are not considered to be a severe problem to source water in B.C. However, individual households, apartments, schools, and office buildings, with old lead pipes or lead-soldered pipes could have unacceptably high levels of lead leaching into drinking water supplies.

The amount of lead in water also depends on the acidity (pH) of the water, its softness, and the standing time of the water. The more acidic the water, the softer the water and the longer the water is in contact with the lead, the more lead will be dissolve into the water. B.C. in general has acidic, soft surface water. Adjusting the pH of water to make it less acidic and corrosive can reduce the amount of lead leaching from the pipes.

In 1989, the GVRD found elevated lead levels in "first flush" drinking water samples in the mornings in many households in the Greater Vancouver Water District. This lead was apparently from lead soldering in the pipes of the homes.

A comprehensive study, however, found low levels of lead in the blood of 24-month to three-year-old children served by the water system (Jin, Hertzman, Peck, & Lockitch, 1995). This finding indicated that despite the elevated lead levels in the first flush of drinking water it was not contributing to any elevations of blood lead levels in children.

Households and schools with lead-soldered pipes were advised to run the tap for about a minute each morning before drinking the water or using it to brush teeth.

Chronic, long-term exposure to elevated levels of lead in water, air, or food can cause numerous adverse health affects in fetuses, infants, children, and pregnant women. The central and peripheral nervous system are the central targets for lead toxicity. Symptoms of lead poisoning include tiredness, sleeplessness, headache, irritability, poor attention span, muscle tremor, memory deficits, and joint pain.

Prevention for lead contamination:

- **In areas where the water has a low pH and is soft, parents and schools should run water taps for approximately one minute in the morning or any time water has been left standing in the pipes for longer than five hours.**
- **Raising the pH of water during water treatment and making the water harder can reduce the amount of leaching from lead contained in solder.**
- **The national plumbing code now requires the use of low lead solder for use in drinking water systems.**

Pesticides, and Persistent Organochlorines

Contamination of water by industrial chemicals and pesticides is a frequent source of concern for the general public. Environment Canada reports that there are more than 35,000 commercial chemicals in use in Canada today, and just how toxic many of these compounds are is not clear (Environment Canada, 1998). Of the many chemical compounds, two families in particular cause concern in the environment: the persistent organochlorines (dioxins, furans, and DDT, which take decades to biodegrade) and the anti-chlolinesterase pesticides (organophosate and carbamate pesticides).

Fortunately in B.C., these chemicals are not considered to be a health problem in our drinking water, due to efforts to handle and dispose of these chemicals properly (R. Copes, personal communication, April 2, 2001; T. Tuominen, personal communication, April 3, 2001).

Until about 10 years ago, dioxin-laced effluent was a frequent by-product of the bleaching process in pulp and paper manufacturing and was released into the rivers and coastal waters of B.C. The dioxins, however, did not persist in the drinking water, but concentrated in sediments and animal tissue (R. Copes, personal communication, April 2, 2001). New production processes have dramatically decreased the amount of dioxins released into the environment, and Environment Canada reports a 95 per cent reduction in dioxin loading in the B.C. environment (Environment Canada, August 2000). Any exposure to these chemicals for B.C. individuals comes from food consumption and not drinking water (R. Copes, personal communication, April 2, 2001).

Health Canada has set maximum acceptable concentrations for numerous pesticides in water, including aldicarb, atrazine, glyphosate (Roundup), and many other common chemicals. The most frequently used pesticides in B.C. are glyphosate and the anti-chlolinesterase pesticides, which disrupt the nervous system of the target pests. Some common organophosphate and carbamate pesticides include phorate, fonofos, terbufos, diazinon, and bendicarb (Environment Canada, 2001). These compounds break down in the environment, but can be toxic at high levels to humans and animals if present in water or foods.

Due to the concentration of agriculture in the Okanagan and the Fraser Valley, these two areas would seem to be the highest concern for drinking water contamination by pesticides. However, water sampling in B.C. has repeatedly found these chemicals to be well below the concentrations established by the *Guidelines for Canadian Drinking Water Quality*. Even in the highly permeable Abbotsford/Sumas aquifer, which has had long-term problems with nitrates, sampling has shown very low levels of pesticides. (T. Tuominen, personal communication, April 3, 2001).

In great part, the absence of documented contamination of drinking water sources in B.C. can be attributed to the attention to responsible handling and disposal of these chemicals. In February 2000, for example, a program to collect and properly dispose of unwanted and obsolete pesticides from farmers and nursery owners in the Fraser Valley brought in more than 33,000 kilograms of pesticides to temporary depots (Environment Canada, 2001). These efforts are applauded and will positively contribute to the health of humans, animals, and wildlife in B.C.

Prevention for pesticide, herbicide, and persistent organochlorines contamination:

- **Carry out risk assessment of water sources to determine potential for contamination.**
- **For water systems assessed as being at risk, monitor for pesticide residuals at the consumers' tap.**

Radionuclides

Radionuclides are the family of contaminants, natural and man-made, that emit ionizing radiation, a known carcinogen (a substance that is capable of causing cancer).

Background radiation is all around us. Each day we are exposed to natural background radiation from cosmic radiation and from radioactivity in air, soil, and food. In B.C., water contamination from artificial radionuclides is not considered a problem, because we do not have a large concentration of industries that use, create, or dispose of radioactive products. However, in some regions of the province, due to rock and soil formation and ore deposits, we do have the presence of naturally-occurring radioactive elements that can contaminate drinking water.

In general, surface water supplies have much lower radionuclide concentrations than groundwater that is in contact with rock that contains radioactive elements. While there are many natural radionuclides, such as Potassium 40, Carbon 14, and the Thorium decay series, the ones of most importance in groundwater in B.C. result from the natural radioactive decay of uranium. These are uranium, radium, and radon.

Uranium

Natural uranium has a long half-life, so it is not its radioactive toxicity in drinking water that is a health concern. Rather it is the chemical effect of high uranium concentrations that can chemically damage the kidney. Guidelines currently put the maximum acceptable concentrations of uranium in water at 100 micrograms/L. Health Canada is now investigating whether this level should be revised downward to 20 micrograms/L.

In B.C, the majority of groundwater supplies are already below the current guideline. Some domestic water obtained from wells or small creeks in the interior of the province exceeds the newly proposed guideline of 20 micrograms per litre.

Radium

Radium is produced from the decay of uranium and generally exists in two radioactive forms, Radium-226 and Radium-228. In water, radium is of interest in that it is most often found in groundwater from deep bedrock aquifers that are surrounded by granite. The current maximum acceptable concentration for Ra-226 is 0.6 becquerels/litre and for Ra-228, 0.5 becquerels/litre. Lifetime exposure to water with radium levels in excess of these levels can increase the chance of bone cancer. Radium in B.C.'s water supply has not been considered a major health risk. Concentrations in domestic water are almost always below 0.02 Bq/litre.

Radon

Radon is a naturally-occurring radioactive gas, resulting from the radioactive decay of radium in soil and rocks. (Radium is the "daughter" of uranium decay, and radon is the "granddaughter.") B.C., like most areas of the world, has areas of low, medium, and high levels of radon. The B.C. Coast, Vancouver Island, and the Lower Mainland—where two-thirds of the province's population resides—have low levels of radon. But in the Interior, there are pockets where radon levels are high, particularly in the Okanagan Valley and around Clearwater, Prince George, Castlegar, and Barriere.

Radon can collect in basements and diffuse through the home, particularly in tightly sealed homes. Inhalation of air contaminated with radon over many years can increase the risk of lung cancer. The Ministry of Health Services estimates that in B.C. about 100 people a year die of radon-induced lung cancer through inhalation of radon in their homes. They recommend that owners of homes in the Interior test for radon in the air inside the homes. Water should be tested only if levels of airborne radon are elevated and no other source of radon in the home can be identified.

Water can contain much higher levels of radon without causing health problems. It becomes a health hazard when aeration of the water—through showering, clothes washing, or spraying of water—releases radon into the air. The U.S. Environmental Protection Agency estimates that for every 10,000 Becquerels per liter (Bq/L) of radon in the water, 1 Bq/L is released into the air. Health Canada and the U.S. EPA consider 0.150 Bq/L (150 Bq/cubic metre) of airborne radon to be elevated. This would require water concentrations of 1500 Bq/L (1,500,000 Bq/cubic metre)—many times higher than any level found in B.C. domestic water. While airborne radon is a concern in some areas of B.C., radon in water has not been identified as a health problem here. Mitigation of radon in the air in homes is recommended if the levels exceeds 800 Bq/m3 (0.800 Bq/L).

Prevention for radon contamination:

- **Test water supplies, if air samples show elevated levels of radon and if no other source of radon can be identified test water supplies.**

Other Contaminants

A number of other chemicals and elements can contaminate water, particularly from pollution from industrial sources. Most of these contaminants are not a serious issue in B.C. at this time unless there is an unexpected spill or leak in an underground storage tank that introduces the contaminants into the water supply. Contamination from petroleum products—oil, gasoline, benzene, and toluene—can make water unpalatable to drink. Usually, however, these contaminants create a strong smell or bad taste to the water at levels well below that considered toxic to humans. Therefore it is unlikely that anyone would drink enough water contaminated with these elements to cause adverse health affects.

[illegible]

On August 1, 2000, an oil pipeline ruptured in northern British Columbia, sending one million litres of light crude oil into the Pine River, which serves as the drinking supply for the town of Chetwynd.

Before the oil reached the town's water treatment centre, intake valves were closed. The clean-up was still not complete by the time snow and ice set in and continued after the spring break-up. The company that owns the pipeline spent $20,000 a day trucking fresh water to the town. Chetwynd has now drilled a well and will be obtaining its water from groundwater sources—which seems to be of higher quality than the Pine River. A number of smaller private wells, however, may have been adversely affected by the oil spill.

Methyl Tertiary Butyl Ether (MTBE)

MTBE is added to gasoline to increase its oxygen content and therefore improve the efficiency and cleanliness of the burning process. MTBE helps to reduce tailpipe emissions and has been added to reformulated gasoline (Joseph, 1999). In recent years, there has been a growing concern in the United States about MTBE exposure. Groundwater concentrations of MTBE are higher there, probably due to the increased density of people and cars.

Most of the studies on MTBE relate more to inhalation of MTBE rather than ingestion of the substance through drinking water. Headaches, dizziness, nausea, and asthma are the major reported health effects from respiratory MTBE exposure at toxic levels (Gullick and Le Chevallier, 2000). Long-term exposure to MTBE is thought to be carcinogenic.

A specific guideline in Canada for MTBE has not yet been established. The U.S. Environmental Protection Agency has now denoted a taste and odour advisory level for concentrations of MTBE greater than 20-40 μg/L (Gullick and Le Chevallier, 2000). The B.C. Ministry of Water, Land and Air Protection has endorsed an aesthetic objective in raw drinking water of 20 μg/L for MTBE (L. Pommen, personal communication, July 31, 2001). Like petroleum products, MTBE imparts an unpleasant taste in water well in advance of its concentration reaching a level to become a health hazard.

In other jurisdictions, common sources of MTBE contamination in water are leaking underground storage tanks and spills from pipelines or fuel trucks, or spills at MTBE manufacturing and storage sites. MTBE easily dissolves in water, is not easily biodegradable, and therefore is practically impossible to remove once it gets into the groundwater supply (Joseph, 1999).

MTBE exposure is not considered a drinking water hazard in B.C. at this time. The limited tests that have been done have found MTBE—at barely detectable levels—in only one well and one community water supply. In the year 2000, the use of MTBE in gasoline was discontinued in B.C. However, MTBE containing products still enter the province through pipelines and road or rail transport. A pipeline break or tanker truck spill could potentially introduce MTBE into a region's water supply.

Disinfection By-Products

The addition of chlorine as a disinfectant to water supplies over the last century has dramatically reduced the rates of illness and death caused by waterborne pathogens. At the turn of the century, prior to chlorination of the municipal water supplies, diarrhea and enteritis was the third leading cause of death in the United States (Centers for Disease Control, 1999). Before chlorination, one out of 600 people died each year of typhoid, a disease that is now virtually eliminated from water supplies (National Academy of Engineering, 2000). Therefore, millions of lives have been saved over the last century by this simple, inexpensive treatment of adding chlorine to our water supply.

In recent years, concern has been raised that chlorination of water creates by-products that may harm human health after long-term exposure. The by-products are created when chlorine reacts with dissolved organic material—particularly the humic substances of decomposing plants and animal matter. Water that is low in organic matter creates few disinfection by-products after exposure to chlorine. Disinfection by-products are more commonly found in treated surface water than in treated groundwater because of the higher level of dissolved organic material in surface water. Concentrations of disinfection by-products can be considerably reduced by pre-treatment of the water through sedimentation or coagulation to remove dissolved organic carbon from the water or by filtration.

Over the last 20 years, a number of studies have raised suspicions that exposure to disinfection by-products over many years—in excess of 40 years—may elevate the risk of developing cancer, particularly bladder cancer. Other disinfectants used to treat water, such as ozone, also create disinfection by-products, but the toxicity of these by-products has not been extensively studied (Mills et al., 1998).

The Battle over Chlorination in Erickson

For a number of years the community in the Erickson Improvement District of East Kootenay B.C. has been refusing to disinfect its water because of opposition to the chlorination process. The water system, which serves about 2,000 people outside Creston, B.C., has tested positive for fecal coliforms repeatedly over the last 10 years and has had two outbreaks of giardiasis. The water supply has remained on a boil-water advisory since 1993.

The medical health officer and other health officials have tried for more than eight years to get the community to treat the water, maintaining that the current water source poses an unacceptable health hazard to customers. Over the years, plans to install treatment have been met with resistance, delay tactics, and even blockades.

"I can't understand how they can continue to say that treating water with chlorine represents a greater health hazard than the bacteria in the water supply," the medical health officer, Dr. Andrew Larder, has said in interviews.

In January 2001, the provincial government appointed a receiver to assume the powers of the board of the Improvement District, to manage the water supply, and to resolve the issue.

Prevention for disinfection by-products:

- **Pre-treat or filter water to remove organic material.**
- **Use lower concentrations of disinfectants or a combination of disinfectants (e.g. chlorine, chloramine, ozone, ultra-violet light) to minimise the formation of disinfection by-products.**

Trihalomethanes (THMs)

Hundreds of chlorinated organic compounds can be produced by the interaction of chlorine with organic-rich raw water. The family of trihalomethanes (THMs) are the most often present and in the greatest concentration, and as such they are used as indicators of total disinfection by-product formation. The most common THMs are chloroform, bromodichloromethane, chlorodibromomethane, and bromoform (Health Canada, July 1993). Of these four, chloroform is the by-product most commonly found in treated water and is the one most extensively studied.

Disinfection By-Products in Port Hardy

For years, decomposing cedar and hemlock in the surface water that serves the town of Port Hardy gave the water the colour of tea. The colour made the water unappealing to drink, but more importantly, the high organic content raised considerable concerns about exposing the community of 6,200 to unacceptable levels of disinfection by-products through chlorination. While the population was exposed for many years to elevated levels of disinfection by-products, there have been no identified elevation in cancer cases (R. Watson, personal communication, April 1, 2001).

In 1999 the municipality entered into a unique public-private partnership with the Edmonton-based company EPCOR Water Services. Under the terms of the agreement, EPCOR designed, built, and now operates a new water treatment facility that features dissolved air flotation and filtration. The $3.6 million plant began producing clear water in April 2000, and concerns about unpalatable colour and unacceptable levels of disinfection by-products are now removed.

Rats and mice exposed for long periods to chloroform in drinking water have a higher rate of liver and kidney tumours. The Federal-Provincial Subcommittee on Drinking Water established the current guideline for THMs in 1993, based on the risk of cancer reported in these animal studies of chloroform.

Since then, new human studies have been published, but the adverse health effects of THMs in humans have been less clear. Five epidemiological studies in the last 20 years have shown a slightly increased risk of bladder cancer from long-term exposure to chlorinated drinking water (Wigle, 1998). It should be noted that smoking is thought to be responsible for about 70 per cent of new cases of bladder cancer.

Epidemiological studies of reproductive problems have been inconclusive, but a study in California did find a slight association with miscarriages (Waller, Swan, DeLorenze, & Hopkins, 1998).

In May of 1997, in order to make sense of the conflicting studies and the relative risk of potential harmful effects, Health Canada convened an expert working group to examine the health risks of chlorination by-products. The group, made up of leading epidemiologists, toxicologists, public health specialists, and water quality experts, assessed all the research to date on the issue. The participants concluded that it was possible (60 per cent of the group) to probable (40 per cent of the group) that by-products over many years of drinking water of with THMs in excess of 220 micrograms/L could increase the life-time risk of developing cancer, particularly bladder cancer. The group concluded that there was insufficient evidence to establish a causal relationship between disinfection by-products and adverse reproductive outcomes. They recommended that more research be done on the health risks and on risk/benefit evaluations (Mills et al., 1998).

Health Canada has since established a multi-stakeholder Chlorinated Disinfection By-products Task Group to oversee a coordinated effort to further estimate the health risks from THMs and to develop risk management recommendations. This is being done through a series of subgroups to evaluate human (epidemiologic) and laboratory animal (toxicologic) evidence of health effects from THMs, drinking water quality data and water treatment facility characteristics, and costs for communities across Canada. The subgroups are likely to have interim reports by the fall of 2001 (Health Canada, November 1999).

Here in British Columbia, the formation of chlorination by-products is considered a public health concern. However, almost all our water systems have been able to maintain THM levels below the current *Guidelines for Canadian Drinking Water* level of 100 micrograms/L recommendation. THM levels are generally higher in other provinces. Health officials in B.C. monitor treated drinking water for the presence of THMs on a regular basis.

The risk of bladder cancer increases with the duration and concentration of THMs, although there is still debate about the exact level of risk. Individuals exposed to high levels over a lifetime may have 1.5 times the risk of those who had no exposure (King & Marrett, 1996). However, the risk of bladder cancer should not be considered in isolation. The lifetime probability of dying from bladder cancer is less than one per cent (National Cancer Institute of Canada, 2001), and smoking is thought to be responsible for at least 40 per cent of bladder cancer deaths (B.C. Vital Statistics Agency, 2001). The Provincial Health Officer's opinion is that the public health risks of waterborne illness from not chlorinating drinking water outweigh the risk of long-term health effects, especially when the levels of THM are kept low.

In the last 10 years it has been an uphill struggle for many public health officials in B.C. to convince communities of the need to chlorinate water. While disinfection by-products may slightly increase the chance that an individual will develop bladder cancer 50 years from now, a few bacteria of E.coli O157:H7 that survive because the water was not adequately chlorinated could kill a child tomorrow. The tragedy of Walkerton could have been avoided if the water had been adequately chlorinated. In Peru in 1991 more than 7,000 people died and 800,000 people were infected with cholera when the country decided to stop chlorinating because of fears of the effects of disinfection by-products (Dowd, 1994; Putnam & Wiener, 1995; Gribble, 1996).

Focusing on reducing the risk of exposure to disinfection by-products at the expense of controlling microbial pathogens may be compared to spending more resources to reduce the chance of being struck by lightning at the expense of increasing your chance of being struck by a car.

Ozonation By-Products

Ozone is becoming a more popular method of disinfecting water in many regions in North America. The process of ozonation, however, also creates disinfection by-products. Although ozone by-products are considered less of a potential heath hazard than by-products produced by chlorine, there are still questions to be answered.

Ozone breaks down complex organic material into smaller compounds called assimilable organic carbons (AOCs). These small organic compounds make a more available nutrient source for bacteria to feed on, and so contribute to bacterial re-growth in the water distribution system. AOCs can be removed by biofilters or by granular activated carbon filters. AOCs are not considered a health hazard in themselves. Rather, they promote bacterial growth in the distribution system, and this may mask the presence of other bacterial pathogens in the water (B. Jones, personal communication, April 3, 2001).

If bromide is in the source water ozonation creates bromate as a potentially carcinogenic by-product. The major natural sources of bromide are salt water intrusion in groundwater or bromide dissolution from sedimentary rocks. Run-off from highways and agriculture, as well as sewage and industrial effluent, can introduce bromide into water (Health Canada, 1998, Bromate). Bromate at high levels can cause abdominal pain, hearing impairment, or kidney failure. Animal studies have shown that ingestion of bromate in high doses in food may be carcinogenic to the kidneys (Kurokawa, Maekwa, Takahashi, & Hayashi, 1990).

Very few water treatment plants here use ozone for disinfection. This situation may change in the future, as more communities consider ozone for primary treatment of the water. Further studies will help in establishing the true risk to health from any ozone disinfection by-products.

Prevention for ozonation by-products:

- **Monitor source water for bromide before using ozone as a disinfectant.**
- **Monitor treated water for bromates.**

Aesthetic Parameters

Drinking water sometimes has attributes that detract from its aesthetic qualities, such as an unusual colour, taste, or odour. Often these do not present health concerns, but they may make the public wary of consuming the water. Aesthetically poor water can also drive people to use unsafe water sources that appear more palatable. The following list of aesthetic parameters for water quality has been chosen for further discussion, because they are frequently the source of questions in health regions in B.C. An explanation of their significance (or non-significance) for health is given.

Copper

Copper is second only to iron as being an essential element we need to consume to maintain health. Elevation of copper is found in water at the consumers' tap in many B.C. drinking water systems due to the leaching of copper from copper pipes. This occurs in conditions when water is relatively acidic.

The *Guidelines for Canadian Drinking Water Quality* has an aesthetic objective for copper in drinking water of less than or equal to 1.0 mg/L. The presence of copper in excess of this level in domestic water supplies can cause green staining of laundry and plumbing (particularly when a source water has high acidity), although copper in this concentration is not a health concern. Copper poisoning can occur in humans if there is ingestion of amounts greater than 15 mg per day (i.e., 15 litres of water containing 1.0 mg/L.).

Colour

In British Columbia, source waters may have high colour—particularly when they originate from shallow lakes or natural reservoirs that may contain decaying wood, leaves, and needles. Colour in drinking water may be due to the presence of coloured organic substances, the presence of metals such as iron, manganese and copper, or the presence of highly coloured industrial wastes, the most common of which are pulp, paper, and textile wastes. Bacteria and pathogens are colourless and, therefore, water colour does not necessarily indicate their presence or absence. However, when colour is associated with high turbidity, this is an indication of a possible increased risk of the presence of micro-organisms (R. Copes, personal communication, April 2, 2001).

Under the *Guidelines for Canadian Drinking Water Quality*, the aesthetic objective for colour has been set at 15 TCUs (True Colour Units.) This is the level of colour that can be detected in a glass of water by most people. The removal of excess colour from water prior to chlorination can have health benefits by reducing the production of disinfection by-products, if organic substances imparted the colour.

Hardness

The hardness and softness of water relates to the amount of dissolved minerals in the water. Water that is hard has high levels of dissolved minerals, particularly calcium and magnesium. Water that moves through soil and rock tends to be hard and, therefore, groundwater supplies are usually harder than surface water. In general B.C. waters are soft due to the predominance of surface water supplies. About 60 per cent of surface waters that have been sampled in B.C. are soft (L. Pommen, personal communication, March 26, 2001).

Hardness and softness of water is not a health concern. Hard water causes the build-up of mineral deposits—scale—in distribution systems, pipes and appliances, such as kettles and hot water tanks. Hard water also causes poor lathering of soap and leads to a build-up of soap scum. Soft water may cause corrosion of pipes and leaching of minerals from pipes, such as lead and copper. Hardness levels between 80 and 100 mg/L (as $CaCO_3$—calcium carbonate) produce a good balance between both extremes.

In planning the treatment for a water system, there may be adjustment of hardness to enhance the effects of disinfectants, to control corrosion of the pipes in the distribution system, to reduce the incidence of lead leaching from pipes and for aesthetic reasons, such as better soap lathering and less formation of scale and soap deposits.

Taste and Odour

Unusual odours or a change in the taste of drinking water are among the most frequent reasons for public complaints to either public health departments or to a water utility.

Odour from water is predominantly due to the presence of organic substances. An odour or adverse taste from drinking water usually indicates some sort of pollution of the water source or some sort of malfunction during the water treatment or distribution processes. In general, pathogens and toxic substances that pose health threats are odourless, and no direct relationship between odour and the presence of coliform bacteria and related pathogens appears to exist. As an overall category, because taste and odour cannot be measured objectively, an aesthetic objective has not been set.

Some odours can be a warning not to drink the water until health officials have tested it. An odour of newly mown grass can be an indication of a cyanobacteria bloom, and odour of gas or oil can indicate fuel or MTBE contamination of the water.

An odour of rotten eggs results from the presence of hydrogen sulphide in the water supply. Because sulphur compounds have a disagreeable taste and odour, an aesthetic objective for sulphide and sulphate, has been set at 0.05 mg/L and 500 mg/L respectively. Sulphur is not considered a health concern.

Manganese

Manganese is regarded as one of the least toxic of all elements. Animal experiments have shown that long-term ingestion at a dose of 1-2mg/g did not result in any immediate effects other than change in appetite and reduction in the incorporation of iron into haemoglobin. Manganese in water, however, can cause dark brown or black staining of tubs, sinks, and laundry that is aesthetically unpleasant. As such, an aesthetic objective for manganese in drinking water has been set at 50 micrograms/L.

Manganese is very common in B.C. wells. Laundry staining from slightly elevated levels can be avoided by adding a stain-preventing additive during washing. Manganese in large doses does cause headaches, apathy, irritability, insomnia, and weakness of the legs.

Fluoride

Fluoride is considered a beneficial nutrient in water because of its positive effect on dental health. All water contains some trace amounts of fluoride, but over the last 50 years, in some places, fluoride has been added to drinking water supplies to protect children from tooth decay. Usually fluoride levels are adjusted to levels between 0.8 to 1.0 mg/L to obtain the maximum protection for teeth. The Canadian Dental Association, the Canadian Medical Association, the Canadian Public Health Association, the Canadian Pediatric Society, Health Canada and the World Health Association support fluoridation of community water supplies.

Community water fluoridation is the most cost-effective way of ensuring children's and adults' dental health, and it is particularly valuable for poor children who do not have access to good dental care. British Columbia, however, has the lowest rate of fluoridation in Canada because of opposition to the process. Only six per cent of B.C.

water systems add fluoride compared to 78 per cent of water systems in Alberta (Hann, 1999). Currently any municipal water system in B.C. wanting to add fluoride to the water must receive public assent through a referendum.

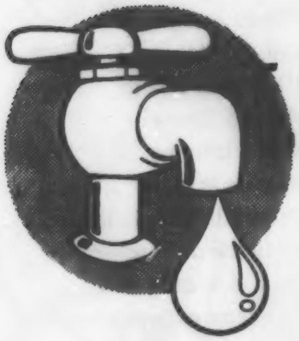
Under the *Guidelines for Canadian Drinking Water Quality*, the maximum acceptable concentration for fluoride in drinking water is 1.5 mg/L. Some groundwater in B.C. contains naturally-occurring levels of fluoride as high as 8-12 mg/L. Public health authorities are not aware of any situations where B.C. residents suffered illness or adverse affects from consuming this much fluoride in drinking water. However, scientific evidence shows long-term consumption of water with fluoride at high concentrations may result in skeletal and dental fluorosis—a deposit of fluoride in the teeth and bones. In the teeth it can cause bright, white patches, and in the most severe cases porous, pitted teeth. When fluorosis happens to B.C. children, it is usually as a result of swallowing too much fluoridated toothpaste. In bones, long-term exposure to elevated levels can lead to increased bone density, bony outgrowths, and increased bone brittleness, but age, nutritional deficiencies and renal insufficiency can all influence the occurrence of these effects (Health Canada, 1996, Fluoride).

Anti-fluoridation groups often cite concerns over possible carcinogenic properties of fluoride as the reason they oppose it, but more than 50 years of epidemiologic studies have failed to show a consistent correlation between fluoride consumption and cancer. Three major working groups (the British Working Party on the Fluoridation of Water and Cancer, the International Agency for Research on Cancer, and the U.S. National Academy of Sciences) reviewed the published studies. All three concluded that the available body of evidence shows no consistent association between the consumption of fluoridated water and the risk of cancer morbidity or mortality (Health Canada, 1996, Fluoride).

The U.S.Centers for Disease Control and Prevention, in August 2001 published a report titled *Recommendations for using fluoride to prevent and control dental caries in the United States*. The report outlines the high cost-effectiveness of community water fluoridation to protect against dental caries (Centers for Disease Control and Prevention, 2001).

It is the Provincial Health Officer's recommendation that the addition of fluoride to levels of 0.8 mg/L in drinking water confers positive benefits to the health of the population and should be implemented by more communities in B.C.

▶ **See recommendation 11.**



From Source to Tap — Reducing Health Risks

This chapter outlines the multiple barrier approach to drinking water quality and introduces the concept of Hazard Analysis and Critical Control Points (HACCP) as it can be applied to a water system. Protecting the water source, ensuring adequate water treatment, maintaining the distribution system, and monitoring the water system—from source to tap—will dramatically reduce the risks to health.

As the previous chapter has shown, there are a number of serious health risks that can arise from contaminated water. Fortunately, many of these risks can be dramatically reduced if we are aware how contamination can enter our drinking water at various critical junctures, and if we have systems at those junctures to prevent contamination or to reduce or remove the contaminants. This is a "multi-barrier" approach to protecting our drinking water.

Multiple Barrier Approach

A focus on the entire system, from source to tap is a far better way of protecting public health than reliance on simple end-product testing. A multiple barrier approach means a series of separate step or components, each of which helps achieve safe water. Barriers include:

- At the source – protection of source water quality by limiting or prohibiting wastewater discharges and other sources of water pollution
- Treatment – adequate treatment such as disinfection and/or filtration
- During storage and distribution – safeguarding water quality during storage and distribution, and
- At the consumers tap – monitoring of the distribution system and enforcement of standards.

Hazard Analysis and Critical Control Points

A practical tool for managing risk and identifying weaknesses in the barriers is the use of a risk management approach called Hazard Analysis and Critical Control Points (HACCP—pronounced hassip). This is a system of process analysis and control originally developed more than 30 years ago by the National Aeronautic and Space Administration (NASA) to safeguard food preparation for space flight. A critical control point is any point in the process where the loss of control could result in an unacceptable safety risk.

HACCP frameworks have now been widely adopted in the food industry, but its principles apply very well to managing and preventing risks to our drinking water and has been suggested as a framework for controlling risks to water systems contamination (Gradus, 2000). The Melbourne Water Corporation is a recent example of how HACCP can be applied to public drinking water supplies (Hellier, 2000).

HACCP has eight basic principles:

1. **The first step is risk assessment.** In water, this means identifying potential hazards to water quality (microbes, chemicals or physical contaminants) and understanding how they contaminate water, how they harm human health, and how they can best be reduced or eliminated. All water systems in B.C. should have a site-specific risk assessment (for the identified hazard) conducted from source to tap, so that risk management plans can be formed to first deal with the most prevalent and pressing concerns.
2. **Risk management planning starts with the identification of critical control points.** These are the points in the entire spectrum of the water system—source water, treatment, distribution, and at the consumer's tap—where hazards are likely to exist or be introduced or where action can be taken to control or eliminate the hazards.
3. **Risk management then proceeds to establish preventive measures, with critical limits for each control point.** At each spot where hazards can be introduced, adopt specific guidelines or standards that serve to alert personnel or officials when hazards may be present. This means, for example, following the maximum acceptable concentrations of various contaminants set out by the *Guidelines for Canadian Drinking Water Quality*, establishing rules for watershed use that when breached could indicate a problem, or establishing fail-safe procedures to ensure the continued operation of water treatment plants.

Further steps to ensure ongoing quality maintenance and improvement are:

4. **Establish procedures to monitor the critical control points.** Regular water sampling, surveillance of activities in the watershed, and monitoring of the distribution system are all examples of procedures that can monitor the critical control points.

5. **Establish corrective actions to be taken when monitoring shows that a critical limit has not been met.** These actions could simply be re-testing the water, or shutting off an intake valve, halting an activity in the watershed, notifying the appropriate authorities, or issuing a boil-water advisory to the public until the safety of the water can be confirmed. These measures should be in place in the emergency plan for all water systems.
6. **Establish procedures to verify that the hazard control system is working properly.** In essence, this is testing of the testing and monitoring of the monitoring. Are tests being taken with enough frequency? At the right time? In the right location? Are the laboratory results accurate? Are the results being relayed to the right people in a timely and effective fashion? Verifying the system is working would include having quality assurance of field sampling, quality assurance of laboratory procedures, and certification of personnel in all areas of water quality assessment and operation of a water system.
7. **Establish effective record keeping to document the HACCP system.** Good record keeping provides the proof the system is performing as expected. Actions can be tracked, problems identified, and improvements noted. Record keeping includes noting the hazards, their control methods, the monitoring of safety requirements, and the actions taken to correct potential hazards.
8. **Continuously seek to improve the quality of the product (in this case water) and the process.** Although HACCP is structured around a series of steps and control points, the process is actually continuous (similar to the concept of continuous quality improvement). In many cases, there are options along the way. For example, different levels of water treatment or different monitoring activities may be chosen, according to the system's needs.

Many of these eight principles are already in place to protect B.C. water quality, yet they can be further entrenched by water providers to ensure the water they are delivering to the consumer is safe. The first action, "analyze the hazards", is the area in which we have the least information.

The HACCP approach has a number of advantages over random spot checks and random sampling of water, which tends to be reactive rather than preventive. Most importantly, a HACCP approach is:

- Based on sound science;
- Focuses on identifying and preventing the most likely hazards from contaminating the water at the most likely junctures for contamination to occur;
- Permits efficient and effective government and public health monitoring, because the record keeping allows investigators and public health officials to see how well a water provider is complying with HACCP requirements over a period of time, rather than how well the water provider is doing on a given day;

- Places appropriate responsibility for ensuring day to day drinking water safety on the water provider, while allowing the government and public health to effectively oversee and regulate the process.

It is expected that larger water suppliers would be expected to have the resources and expertise to undertake professional quality HACCP assessments. Smaller waterworks would need the assistance of water quality experts in risk assessment and/or public health engineers to draw up and manage a HACCP plan.

Using the HACCP framework, we can look at B.C.'s water system from source to tap to identify where we have threats of contamination entering the water system. In general, there are four critical control points (similar to the multiple barrier approach):

- At the source – protection of source water quality by limiting or prohibiting wastewater discharges and other sources of water pollution
- During treatment – adequate treatment such as disinfection and/or filtration
- During storage and distribution – safeguarding water quality during storage and distribution, and
- At the consumers tap – monitoring of the distribution system and enforcement of standards.

Continuous Quality Improvement

The American Water Works Association (AWWA) in association with the Water Environment Federation has developed a continuous quality improvement program QualServ (American Water Works Association, 2000). The goals of this program are to:

- Increase customer satisfaction
- Improve efficiency
- Reduce the need for additional regulations
- Receive recognition from customers, owners and regulators
- Harness the knowledge and energy of all stakeholders

QualServ has various tools under development—Self Assessment, Peer Review, Benchmarking Clearinghouse, Accreditation and Customer Satisfaction. It appears to be a useful process tool to support an organizational culture of continuous quality improvement to achieve the outcome of improving water quality. Being sponsored by AWWA it will incorporate AWWA standards to which most North American utilities refer. QualServ has been developed for use by both large and smaller water utilities.

▶ See Appendix B for QualServe web address.

Multiple Land Use in the Courtenay/Comox Water System

Comox Lake, via the Puntledge River, supplies 32,000 residents of Courtenay/Comox with drinking water. It is a large lake surrounded by private land with high activity and multiple use. Boating occurs on the lake, houses and campsites exist around it, logging takes place on the hillsides above it, and there is a fish and game club shooting range beside it. The Canadian Armed Forces carries out rescue training on the lake, and BC Hydro has a dam and hydroelectric power station on it.

With so many users, it would be impossible to stop activities in this watershed. Instead, the local medical health officer has held a series of meetings with the owner of the water system, the owners of the land surrounding Comox Lake, the public, and with representatives from government agencies who have regulatory authority over the watershed. All involved have identified measures they are taking to reduce the risks of contamination of the drinking water source to enable the continued supply of good quality source water to the residents of the two towns.

To date, the collaborative attention to protecting the water has been successful. Regular monitoring shows low levels of fecal coliforms and turbidity throughout the year. The water is chlorinated enough to kill microbes and to ensure there is no bacterial re-growth in the distribution pipes.

So far, there has been no documented outbreak of waterborne illness to date in the community.

Without filtration or other advanced treatment, such as ultraviolet radiation, the potential for parasite contamination remains.

This illustrates that safe drinking water can still be obtained from multi-use watersheds, as long as the source water has low turbidity and is adequately disinfected. The risk of fuel spill contamination continues to be a concern.

The challenge for the future will continue to be balancing the interests of all the users of the watershed while maintaining good quality water.

Protecting the Water Source

The first way to keep contamination out of our water supply is to do our best to keep contamination out of the source. In general, water that is of good quality at the start will not require vast amounts of expensive treatments to make it potable to the consumer at the other end.

The 1999 Auditor General's report *Protecting Drinking Water Sources* discussed at length the stresses and strains that are now facing our drinking water sources. In particular, it discussed the impact of logging, cattle grazing, mining, outdoor recreation, transportation, agriculture, and human settlement on source water quality. The report made a number of recommendations that have been reviewed by the provincial government. The Provincial Health Officer agrees with many of the recommendations, particularly the need to improve the protection given to drinking water sources and the need to develop water quality objectives for all community watersheds as a matter of priority.

It must be noted, however, that there are limitations on the water quality improvements that may be achieved solely as a result of better protection or management of the land that recharges water sources. This is based on the inevitability of the presence of such pathogens as *Cryptosporidium* and *Giardia* in B.C. water, and on the difficulty in maintaining low turbidity in B.C. surface water, particularly during times of high rainfall or during the spring snowmelt. Good source protection can prevent some contaminants from entering the water supply, but even the most pristine watershed, in which no human activity occurs, can still harbour contaminants harmful to human health.

Recently, some groups have been focusing on the issue of banning all activities in community watersheds as being of paramount importance to protect the water and safeguard human health. Some water districts, such as Greater Vancouver, own or have control over most of the watershed and can prevent human activities from occurring. But from the public health perspective, it is not necessary, nor in some instances even desirable, to ban all activities. What is more important is to understand what risks the activities may introduce into the water and take steps to ensure the risks are reduced, including the implementation of full water treatment, including filtration, when it is necessary.

One of the most contentious issues is logging in watersheds. B.C.'s economy has been built through forestry, and it is still one of the larger employers in the province. From the broader public health perspective, British Columbia should not focus solely on the quality of our drinking water as the most important factor that imparts good health to its citizens. Good health is also promoted by meaningful employment, by a healthy economy, and by having a tax base that can support good education and health care. Two of the greatest predictors of poor health are unemployment and poverty. Good health is also promoted by opportunities to enjoy the outdoors through recreation and physical activity.
British Columbia must balance out the competing needs and issues as they relate to the well-being and good health of the citizens of this province.

It is neither feasible nor necessary to ban all logging in watersheds that feed drinking water supplies. But it is feasible, and indeed necessary, to ensure that any logging that takes place is done carefully and with the protection of the drinking water source quality as one of its primary concerns. Logging practices—and any other activity in watersheds—must be done so as not to increase the run-off and turbidity in the water. There must be greater force in the regulations to ensure that when forestry or mining companies or other groups use watershed land, the drinking water source is protected. If companies or groups degrade the source water quality, they must bear the responsibility and cost of returning the water to original state. User fees for hikers in watersheds to maintain appropriate latrine facilities to prevent fecal contamination of water is one example of this principle. In short, the polluter should pay for the cleanup, not the citizens who use the water.

The Greater Vancouver Water District

Two million people—about half the population of the province—have their water provided by 18 municipalities that purchase their water from the Greater Vancouver Regional District. The water sources for the Greater Vancouver water supply system are the Capilano, Seymour, and Coquitlam watersheds.

The Greater Vancouver Regional District leases the watersheds and ensures that there is controlled access and controlled activities within those watersheds. For the past 15 years, the District has embarked on a systematic water quality improvement program that has included increased monitoring and improved disinfection and treatment. An ozone disinfection plant was recently installed on the Coquitlam water source, and construction for a filtration plant on the Seymour system will start in 2002 for completion in 2005. A Web site www.gvrd.bc.ca/services/water provides the public with current information about the water system, water quality and planned improvements in the water system.

Despite a restricted and enclosed watershed, the source waters have episodes of increased turbidity following periods of high rainfall. A recent study titled *Drinking Water Quality and Health Care Utilization for Gastrointestinal Illness in Greater Vancouver* concludes that with increased turbidity in the Greater Vancouver water supply there is evidence (based on a statistical association) of an increased incidence of intestinal illness in the population (Aramini et al., 2000). This illustrates that even a highly protected and carefully managed watershed may need filtration to prevent some waterborne illness.

Watershed management should be a transparent, multi-stakeholder process of arbitration or compromise between the goals for water quality protection and the interest or need for land use, development, or management of natural resources.

Watershed protection plans should be based on site-specific conditions. A "one-size fits all" approach to source protection is not effective, because there can be variations in the physical characteristics of the surface water, land use, land ownership, and potential risks. This is why assessment of each water supply is necessary, so that specific risks to the quality of the water can be identified in each watershed and be specifically prevented or managed.

Nevertheless, there are some general principles that can be applied to the protection of both surface water and groundwater to help reduce the chance that contaminants will enter the water supply.

Surface Water

The quality of surface water is affected by a number of natural and land use factors. Natural factors that can introduce contaminants include heavy rainfall, steep slopes, poor soil drainage, lack of vegetation, and resident wildlife populations. Land use sources of contamination include agricultural practices, such as use of pesticides and fertilizers and livestock grazing, forestry, mining, recreation, roads, urban development, and the discharge of municipal or industrial waste water into the source.

In general, B.C.'s surface water is less subject to industrial or agricultural pollution from human or livestock activity than water in other more populous Canadian provinces and the United States. Many of our watersheds are wilderness areas. The Greater Vancouver watersheds, which provide water to half of B.C.'s population, have highly restricted access, and very little activity is permitted within the watershed. This, however, is not a guarantee that the source water will be safe without disinfection and filtration. Filtration will be needed to address ongoing water quality issues such as turbidity because turbidity is increasingly being identified as being associated with illness in the population.

▶ **See Turbidity page 59.**

Surface Water Protection Measures

The following are some of the steps that can be taken to reduce the potential for contamination of surface water. Note that these measures are not necessary for all surface water supplies, and should be applied to specific areas where hazard identification and risk assessment has revealed specific hazards to be a problem:

- **General protection:** Land acquisition; trespass control; watershed inspection programs; reservoir use restrictions; stream and reservoir buffers.
- **Protection from agricultural contaminants:** Soil conservation practices (conservation tillage, contour farming, terracing, grassed waterways); water conservation structures (farm ponds and gully control structures); grazing restrictions in watersheds; animal waste management facilities (to ensure manure run-off does not enter the water supply).
- **Protection from forestry contaminants:** Buffer strips; proper design and construction of roads, skid trails, and landings; post-forestry erosion control. Road and skid trail construction are the most important aspects, because they are responsible for most of the erosion impacts and turbidity in the water.

- **Protection from urban contamination:** retention basins; infiltration devices; storm water diversion; restriction of the density and location of urban development in relation to the surface water supply; monitoring of septic fields; repair of malfunctioning septic systems.

Research Needs

To achieve maximum source water quality, more research is needed to be able to answer some key questions:

- Can turbidity, as a single indicator of source water quality, be used to predict increased waterborne disease risks? If so, at what level of turbidity is the risk increased?
- What measures are needed to minimize turbidity in source waters?
- How can the effects of seasonal weather conditions (rainfall, snowmelt, etc.) on water source quality (turbidity or presence of animal waste) be minimized in a watershed?
- What concentrations of animal (or human) waste contribute to outbreaks of disease?
- How can concentrations of animal (or human) waste be controlled in watersheds to minimize the risk of waterborne illness?
- What are the health effects of boating on lakes and other surface water sources?
- How can nutrient levels (such as nitrogen and phosphorus) be minimized in source water to prevent algal growth and unacceptable levels of disinfection by-products?
- How can amounts of dissolved organic carbon be kept low in source water to prevent the formation of disinfection by-products?

Government or other research bodies should endeavour to have some of these questions answered through scientific research.

► **See recommendation 30.**

Groundwater

Groundwater is water that is in aquifers and wells below the earth's surface. In B.C. about 25 per cent of all drinking water comes from groundwater sources. In all, about 750,000 British Columbians rely on groundwater for their drinking water. There is a limited understanding of aquifer location, size, quantity, and quality throughout B.C. Only a small proportion of all the presumed aquifers in B.C. has been mapped. Since 1994 an inventory of aquifers in B.C. has been underway. To date, some 420 aquifers have been identified and mapped. There may be large quantities of good water below ground that have not yet been discovered.

In general, groundwater is less susceptible to contamination than surface water, but it is still not immune. Some aquifers—called unconfined aquifers—are relatively shallow or separated from the surface by layers of silt, fractured rock, permeable soil through which water and contaminants can leach from the surface. Run-off from a farmer's field recently spread with manure or flooded or leaking septic fields, for example, can introduce microbial pathogens. Other aquifers—called confined aquifers—have a layer of impermeable clay or rock that prevents surface contaminants from entering. However, confined aquifers may be in contact with rocks that introduce mineral or chemical contaminants such as arsenic. The source of the water replenishing the confined aquifer may not be known and may be vulnerable to contamination. If an aquifer becomes contaminated, it can be harder to detect and very difficult to remediate. Contaminated wells or aquifers may have to be abandoned.

Shallow unprotected aquifers that are replenished by surface water present special risks. If they become contaminated with nitrates and other chemicals, the problem may persist for decades. Clean-up may not be possible or, if possible, very expensive. The Walkerton tragedy occurred in part because a poorly sealed well close to farm land allowed farm run-off carrying *E. coli* O157:H7 and *Campylobacter* to contaminate the town's well water source.

Groundwater in Prince George

The city of Prince George has been using groundwater as its drinking water source since the 1960s. It relies on a series of shallow, unconfined aquifers fed by water from the Nechako River.

The river water replenishes the aquifers by seeping through layers of soil, gravel and rock. This natural filtration process removes many microbiological, physical and chemical contaminants, leaving the water in the aquifers relatively contaminant-free. The city then chlorinates the water from all but one well before distributing it.

The shallow aquifers, however, are highly vulnerable to surface contamination. Train tracks and a highway run over top of the aquifers, and a diesel fuel spill in 1997 still has the potential to contaminate one well. Nearby septic fields also pose a potential risk.

Groundwater Protection Measures:

- **General Protection:** Many well water quality problems stem from improper well construction, maintenance, operation, or abandonment. Wells should be constructed, maintained, operated, and abandoned to standards specified in regulations. New groundwater sources and private wells, and existing groundwater sources and wells that have never been tested or are newly suspected of being contaminated, should be tested for the presence of microbiological, physical, and chemical contaminants, particularly arsenic and nitrates.

- **Protection from agricultural contamination:** Fertilizers and manure should be applied far away from wells and unconfined aquifers to avoid nitrates washing into wells; manure piles should not be situated on hillsides above wells or within 100 metres of a well; wells should be sealed and flood-proofed; old wells should be properly sealed with a bentonite seal, not concrete. (Over time, concrete will shrink and crack, allowing surface contaminants to travel down the well casing into the aquifer). Dead animals should not be buried near wells or over or near unconfined aquifers.

- **Protection from urban contamination:** Septic systems must be monitored and maintained (pumped out every three to five years). Malfunctioning septic systems must be repaired; old, underground oil tanks should be removed; cleaners, oils and antifreeze should not be flushed into septic fields or dumped near wells or unconfined aquifers; landfills and garbage dumps should not be located near unconfined aquifers; care should be taken placing and transporting industrial fuels and chemicals to avoid spills and accidents.

- **Protection from salt water intrusion:** In coastal regions, heavy withdrawals from aquifers can cause salt water from nearby ocean water to replace the freshwater in the emptying aquifer. Water must not be withdrawn from aquifers at rates greater than the aquifer can replenish itself.

Water suppliers whose source water comes from aquifers should develop well protection plans in consultation with the local environmental health officers and the Ministry of Water, Land and Air Protection, in order to address some of the risks of groundwater contamination. The *Drinking Water Protection Act* has provisions for water suppliers to develop and implement well protection plans.

A well-protection tool kit that describes measures to help individuals and communities do this has been developed and disseminated by the Ministry of Water, Land and Air Protection. The new *Drinking Water Protection Act* provides the necessary legislative framework for developing regulations to protect groundwater in B.C.

Ensuring Adequate Water Treatment

Water treatment methods have advanced so much in the last century that raw sewage can now be rendered into safe drinking water—if the community is willing to pay the high price tag for such intensive treatment. Indeed, in some countries where water supplies are scarce, drinking water is continually recycled from wastewater. In other countries with poor supplies of fresh water, desalination plants remove the salt from the ocean water to produce the community's drinking water. In short, treatment of water can be as advanced as the community or government can afford and is willing to pay. The crux of the issue in B.C. is ensuring that we are getting the level of treatment we need to prevent waterborne disease and to provide aesthetically pleasing, safe water—in a cost-effective manner.

Log Reductions

When water is treated, public health engineers speak in terms of "log reductions" of contaminants in the water.

If, for example, water has 100 *E.coli* bacteria and after treatment all but one are removed, that is a two log reduction—or 99 per cent of the bacteria are gone. Log reductions are the following:

- 1 log – 90 % removed
- 2 log – 99 % removed
- 3 log – 99.9 % removed
- 4 log – 99.99 % removed
- 5 log – 99.999 % removed
- 6 log – 99.9999 % removed

Most water treatments aim for at least three to four log reductions of contaminants, based on a method developed by the U.S. Environmental Protection Agency.

Some community representatives in B.C. have expressed the desire for the Ministry of Health Services experts, public health engineers, or the Provincial Health Officer to recommend one standard treatment that could be used throughout the province to ensure high quality drinking water. This, however, cannot be done. One size does not fit all.

What does make sense, however, is treatment standards that require log reductions for specific organisms that are found in B.C. waters: bacteria, viruses, and protozoa, particularly *Giardia* and *Cryptosporidium*. Each community must assess its own water treatment needs and treatment goals and find the treatment process that will work best in that location. Each water system needs to take into account the source water—its temperature, turbidity, organic content, and most prominent microbiological and chemical hazards—and the manpower available to run the system. Pilot testing should be done, because what looks good on paper sometimes can't be made to work in practice. There are many aspects that must be carefully considered that are site-before putting in place a treatment system (L. Benjamin, personal communication, April 2, 2001).

▶ **See Log Reductions information box, page 85.**

▶ **See Treatment Standards, page 34.**

What follows are the main treatment methods used to render raw water into potable water. In some cases they may be applied individually, but increasingly they are applied in various combinations to achieve the desired water quality. A water treatment plant, for example, may combine a series of steps such as preliminary sedimentation, followed by flocculation, followed by filtration, with a final addition of a small amount of chlorine before the water is sent through the distribution system. A further dose of chlorine may be added at secondary disinfection stations along the distribution line.

Disinfection

Disinfection is a process that kills or inactivates organisms present in the water. Protecting the public from waterborne illness most often necessitates some degree of water disinfection. Under B.C.'s Safe Drinking Water Regulation, all surface water supplies must be disinfected. An exemption may be granted by the medical health officer if the water provider can demonstrate that a surface water source is free of microbiological contamination and that there is source protection and other measures to increase the confidence that contamination is not occurring.

The common methods of disinfection are chlorination (in different forms such as chlorine gas, chloride dioxide, and sodium or calcium hypochlorite), ozonation, and ultraviolet radiation. Chloramination—a mixture of chlorine and ammonia—is also used as a method of disinfection, however chloramine is a weak disinfectant and is more often used as a secondary disinfectant. Each method of disinfection has advantages and disadvantages (Table 5).

Disinfection effectiveness for a chemical disinfectant is measured in terms of residual concentration and length of contact time required to achieve the desired inactivation. One of the most important considerations in assessing disinfectants is balancing inactivation or effectiveness with by-product formation. For ultraviolet (UV) disinfection systems, effectiveness is measured in terms of UV dose, the intensity, and the exposure time.

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Table 5: Advantages and Disadvantages of Four Disinfectants

Disinfectant	Advantages	Disadvantages
Chlorine (includes chlorine gas, chlorine dioxide, sodium or calcium hypochlorite)	• Effective against most micro-organisms. • Inexpensive.	• Does not inactivate protozoa such as *Giardia* and *Cryptosporidium* • Creates undersirable by-products such as Trihalomethanes. • Toxic to fish at high levels.
Chloramine	• Carries disinfection to the ends of the distribution system. • Effective in minimizing biofilm in distribution pipes.	• Long contact time required. • Not suitable for primary disinfection. • More toxic to fish than chlorine.
Ozone	• Very effective. Can kill *Giardia* and other parasites if enough contact time. • Removes unpleasant tastes and odours.	• Requires secondary disinfection. • Relatively expensive. • May form disinfection by-products, *e.g. Bromate*
Ultraviolet radiation (UV)	• Very effective for viruses and bacteria. • No harmful residues. • Simple to operate and maintain. • Relatively inexpensive.	• Effectiveness against *Giardia* and *Cryptosporidium* has not yet been conclusively established. • Requires secondary disinfection. • May require pre-treatment by filtration to remove turbidity.

Chlorination is most commonly achieved by the addition of chlorine gas or liquid sodium hypochlorite (similar to household bleach) to the water supply. It requires relatively short contact time for effectiveness against bacteria and viruses. Chlorination's advantages are that it is cheap and effective and has been used for almost 100 years with tremendous success in inactivating deadly microbes and preventing waterborne illness.

▶ **See Historical Role of Public Health page 11.**

Its disadvantage is its potential to create disinfection by-products such as Trihalomethanes (THMs) and haloacetic acids (HAAs), which may be carcinogenic when Chlorine comes in contact with water containing dissolved organic compounds. As well, there is evidence that chlorination does not inactivate *Cryptosporidium* oocysts. It may not be completely effective at inactivating *Giardia* cysts, unless the chlorine has a long contact time with the contaminated water. Chlorine can also impart a taste to the water and may increase the corrosivity of the water. Corrosivity causes corrosion in the distribution system.

Ozone (O_3), like chlorine, is a powerful oxidizing agent. Created when an electric current is run through air or oxygen, ozone can be bubbled through water to kill microbes. It has been used in Europe for many decades. Ozone is an effective disinfectant for most waterborne pathogens. Ozone is also effective in eliminating or controlling colour, taste and odour problems, and it rapidly converts back to oxygen. It can kill protozoan oocysts if it has a long enough contact time with the water—something that is not always possible to do in large municipal systems that deliver large volumes of water to customers. Ozone breaks down complex organic material into assimilable organic carbons that are more available as a protein source for bacterial re-growth in the distribution system, but these can be removed by biofilters. Ozone also creates bromate as a potentially carcinogenic by-product if bromide is present in the source water. Ozone is much more expensive to operate than chlorination. Like chlorine, ozone's effectiveness is reduced in cold water, which is a concern for some water suppliers in B.C. Because ozone does not leave a disinfection residual, it does not carry its disinfection capability to the ends of a water distribution system. Therefore some "biofilm" or bacterial re-growth can occur in the distribution pipes. When ozone is used, secondary disinfection is usually required and can be accomplished with the addition of a small amount of chlorine or chloramines to prevent microbial re-growth and to inactivate microbes that may gain access to the distribution system.

Ultraviolet (UV) radiation is used to disinfect water by shining UV light through the water. Most UV lamps operate at a wavelength of 254 nanometres, although new lamp technologies are based on a range of wavelengths with greater germicidal properties. The UV light penetrates the cell wall of the organism and is absorbed by the genetic material of the micro-organisms. Radiation absorption prevents the microbe from reproducing. UV radiation is very effective against bacteria, and new evidence is emerging that it may be effective against *Cryptosporidium* cysts (Clancy, 2000). Its effectiveness for *Giardia* has not yet been established. UV disinfection may be much less expensive to build and operate than membrane filtration and ozonation. It appears to be a promising emerging technology for water systems with sand filtration for very low turbidity source waters. However, water with a lot of silt or other particulate matter can shield the bacteria and viruses from the UV rays. Therefore, source water should have some pre-treatment, such as sedimentation or filtration, to remove turbidity. Similar to ozone, UV does not carry a disinfection residual to the ends of a water distribution system. Thus, secondary disinfection is usually required with chlorine or chloramines. UV is very promising for small water systems in combination with cartridge filters for sediment removal (R. Watson, personal communication, April 1, 2001).

Secondary Disinfection

Secondary disinfection is the addition of a disinfectant—usually chlorine or chloramine—following the primary disinfection at some point or points along the distribution system. This is done to prevent re-growth of bacteria and microbes in the pipes and to inactivate any microbes that gain access to the distribution system. The quality of water leaving the treatment plant may be good, but by the time the water reaches the domestic tap, some microbes may have reproduced enough or entered the system to cause health or taste concerns. In large water systems such as Greater Vancouver, secondary chlorine disinfection stations are constructed at intervals through the distribution system in order to maintain the disinfection residual at the ends of the system.

Chloramine, a combination of ammonia and chlorine, is effective for use as a secondary disinfectant after a primary (more effective) disinfectant such as chlorine, ozone, or ultraviolet has been used. Chloramine is a weaker disinfectant requiring a long contact time, but it carries its disinfectant capacity to the ends of the distribution system and is effective in reducing the amount of bio-film growth that occurs on the inside of water pipes. It is more toxic to fish than chlorine, and some communities have rejected its use on this premise.

Sedimentation, Coagulation and Flocculation

Water that is left to sit for a short time has some of its larger particles settle to the bottom. The clearer water left on top can then be directed into the water system. This principle of clarifying water has been used for centuries—the Romans had settling ponds at the heads of some of their aqueducts. The process of sedimentation has been helped with the addition of coagulants—compounds that neutralize charges so that particles stick together. Flocculation is a process that combines the small particles into large particles. Commonly used coagulants are alum (aluminum sulphate), ferric sulphate, ferric chloride, and slaked lime. Ancient Egyptians used alum to settle particles in water around 1500 B.C.

Outbreak Spurs Changes in Revelstoke

For years the town of Revelstoke, B.C., did not disinfect its water supply. The source for the town of 7,500 was a pristine stream, Greeley Creek, which flows through a remote valley, gathering water from a mountainside watershed that had almost no human activity. The community felt treatment was unnecessary.

Then, in 1995, a large number of the residents were infected with one of *Giardia*, *Campylobacter*, *Cryptosporidium* or *Yersinia*, probably all from wildlife feces, after a heavy rainfall. Immediate chlorination of the water supply was implemented.

After further consultation, the municipality decided to install a state of the art micro-filtration plant—the first of its kind in B.C. A municipal grant from the provincial government was obtained for half the $6 million capital cost of the filtration plant, and the community pays the other half through user fees.

The micro-filtration membrane system features millions of hollow tubes with microscopic pores. The raw water flows through the pores from the outside into the hollow tube, in the process filtering out all particles greater than 0.2 microns such as parasites and bacteria. Every two hours, compressed air is blown up the hollow tube to backwash the filter. The dislodged debris is washed into a settling pond.

A small amount of chlorine is added to the filtered water to kill viruses and maintain water quality to the user's tap. The annual costs to the users is now $225, less than $0.61 a day per household.

While sedimentation, coagulation and flocculation do remove some microbes, they do not remove them all. They can be used as a pre-treatment to reduce the amount of suspended organic material and particles before disinfection by chlorination, ozonation, or UV radiation. Combinations of sedimentation, coagulation and flocculation are most effective when used as pre-treatments to improve the performance of filtration.

Filtration

Filtration is the earliest form of water treatment. Four thousand years ago people in India filtered water through charcoal. By the mid-18th century, it was recognized that filtering dirty water through sand produced cleaner water at the other end. By the mid-19th century, slow sand filtration was a common form of water treatment. Today there are a number of available filtration technologies: slow sand, enhanced slow sand, rapid rate, granular activated carbon filters, anthracite filters, and membrane filters. They have one aspect in common: they work by trapping contaminants and removing them from the water. The different technologies vary in the amount of contaminants and the size of particles they can remove. All filters have to be cleaned periodically in some fashion, either through backwashing or through scraping off the layer of debris that builds up on the surface of the filter.

Filtration that passes water through a bed of sand, anthracite, diatomaceous earth, or a combination of materials can be very effective at removing *Giardia*, *Cryptosporidium*, and other microbes. A form of pre-treatment such as sedimentation, coagulation, and flocculation can enhance the filtering performance. Their advantage is that they can be less complicated and expensive to operate than the membrane filter technologies.

Membrane filtration passes water through a polymer skin of tiny pores that are too small for viruses, bacteria, and parasites to pass through. Developed by the pharmaceutical and semi-conductor industries to produce ultra-clean water, membrane filtration is named for the various sizes of pores in the membrane. The filtration technologies are named for their pore sizes. Microfiltration filters out most bacteria and protozoan cysts and oocysts. Ultrafiltration filters out most bacteria, cysts, and viruses. Nanofiltration has even smaller pore sizes and filters out the microbial pathogens as well as smaller chemical compounds such as sugar and pesticides. Reverse osmosis removes the smallest particles from water, including salt. It works by molecular diffusion across a membrane from high pressure to low pressure chambers. Reverse osmosis is the most expensive of the water treatment technologies to operate. It can be used to make ocean water safe to drink, so is an option for remote locations that don't have access to fresh water or community water systems.

Filtration plants are much more expensive to build and operate than other forms of treatment. Also, all filtration requires regular backwashing of the filters to remove debris buildup. The cleaning requirements of the filters vary from site to site because of variations in the amount of organic material in the water or in the amount of minerals in the water capable of producing scale build-up on the filters. Regular inspection of the integrity of the polymer membranes is also needed to ensure that microscopic tears or holes do not allow larger particles to pass through.

From the public health perspective, filtration systems will be increasingly needed on B.C. water systems because of the need to remove parasite cysts and oocysts from the water supply. Since filtration plants are generally more expensive to build and operate than chlorine disinfection systems, filtration plants should be added first to the water systems that show the greatest need, based on public health risk assessments. Currently in B.C., there are 11 filtration plants in municipal systems and 27 on First Nation reserves (Table 6).

Table 6. Filtration Plants in British Columbia

Water Systems	Slow Sand	Enhanced slow sand	Rapid Rate	Membrane
Municipal				
100 Mile House	X			
Rossland	X			
Hazleton	X			
Chetwynd			X	
Dawson Creek			X	
Enderby			X	
Grindrod			X	
Kitimat			X	
Penticton			X	
Trail			X	
Revelstoke				X
First Nations				
Anahim Lake	X			
Boston Bar	X			
Gitanmaax	X			
Glen Vowell	X			
Klemtu	X			
Lytton	X			
New Aiyansh	X			
Soda Creek	X			
Spuzzum	X			
West Moberly	X			
Ahousat		X		
Bella Bella		X		
Hartley Bay		X		
Gitsegukla		X		
Kitkatla		X		
Metlakatla		X		
Moricetown		X		
Opitsaht		X		
Port Simpson		X		
Sliammon		X		
Tache		X		
Tachet		X		
Kamloops			X	
Skidegate			X	
Blueberry				X
Doige River				X
Middle River				X

Source: Lawrence Benjamin, M.Eng., P. Eng, CH2M Hill Canada Ltd.

Note: Some improvement districts and other non-municipal systems also have filtration plants. A province-wide listing is not available.

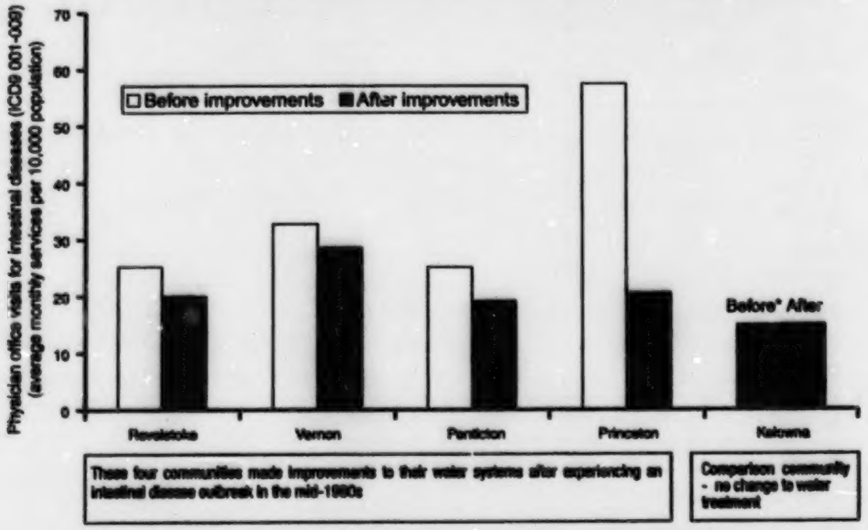
Outbreaks of waterborne disease can be predicted and prevented. Unfortunately, it often seems that communities wait until a serious outbreak occurs before spending the time, energy, and money to treat their water. Making improvements after an outbreak has health benefits (Figure 8), but we shouldn't have to wait for large numbers of people to become sick to install appropriate treatment methods. Adopting treatment standards for microbial pathogens could spur this process along.

Water Improvements Make a Difference

Five Okanagan communities experienced outbreaks of intestinal disease in the mid-1990s. After the outbreaks, four of the communities made improvements to their water systems.

Improved water treatment in Revelstoke, Vernon, Penticton, and Princeton were associated with a decline in doctors' office visits for intestinal illnesses, while Kelowna—with no change to its water treatment—showed no change (Figure 8).

Figure 8: Intestinal Illnesses Before and After Improvements to Water Systems, Four B.C. Communities, 1992 - 2000*



* Data are for the nine-year period January 1992 to December 2000. For Revelstoke, Vernon, Penticton, and Princeton, the time periods are before and after water system improvements were made (in 1995, 1996, 1997, and 1997, respectively). For Kelowna, the time periods are before and after a 1996 outbreak of *Cryptosporidium*. Source: Medical Services Plan claims database. Economic Analysis and Negotiations Support, MSP. Data provided by Population Health Surveillance and Epidemiology, B.C. Ministry of Health Services.

Maintaining the Distribution System

Once the water has been treated, a network of pipes and relay stations sends it to homes, businesses, and institutions. Water can leave the treatment plant free of pathogenic microbes and chemicals, but can become contaminated along the way to the user.

Maintenance and Repair

Distribution systems and infrastructure must be regularly maintained. Secondary disinfection can reduce the growth of bio-film in the pipes, but regular flushing and cleaning of the water mains must be done to prevent build-up. Old pipes may need to be replaced to prevent water main breaks. Leaks and broken mains must be promptly repaired, as these are often ways that contaminants enter the system, particularly if pressure drops in the system. The maintenance of pressure within the distribution system is vital to prevent contamination.

Equipment such as chlorinators can break or be temporarily taken out of service for repair. Unless there is back-up equipment to cover these periods of repair, unchlorinated and potentially contaminated water can circulate through the system, reseeding bio-film and creating positive test results. Water systems should have some built-in back up for times when the main disinfection equipment is not working.

In May 2001 tampering and vandalism at the Langley and Maple Ridge waterworks illustrate that reservoirs and waterworks must be monitored and security breaches prevented. Sites in the distribution line that are at risk for cross-connections and backflow contamination must be remedied.

Cross-Connections and Backflow

The greatest risk of contamination during distribution comes from cross-connections. A cross-connection is any place in the distribution system in which clean, treated water can come into contact with contaminants, unpotable water or waste water, such as sewage. The seriousness of this risk is magnified because there is no barrier between the consumer and the contamination.

Backflow—in which the water in the main reverses direction because of pressure differences—can result in cross-connections. An open water hose attached to a house and left in dirty pond or irrigation water can cause a backflow of contaminants into the water system if there is a drop in pressure behind it on the main line. This is a form of siphonage, and contaminants can literally be sucked into the treated water system. Backflow can also occur when the pressure in a contaminated source is higher than the pressure in a water system (such as through an elevated chemical tank). The excess backpressure forces contaminants into the drinking water

Cross-Connection in Burnaby

On November 2, 1987, a break in the municipal water line in a Burnaby industrial park resulted in the water being shut off for a few hours. In order to keep manufacturing, a local paper product plant connected a hose from its main drinking water system to an auxiliary water system that drew water from the Fraser River.

With the drop in pressure created by the main line repair, the river water backflowed into the plant and into a section of the municipal pipes. Both the plant and the contaminated municipal pipes had to be flushed and disinfected.

A backflow prevention device was subsequently installed at the plant.

system. Backflow—either backsiphonage or backpressure—can contaminate water at a single home or building, or can introduce contaminants into the main distribution system. Leaks and water main breaks, even temporary repairs and shut-offs to certain sections of the piping, can create drops in pressure that promote backflow.

Preventing cross-connections in the distribution system is essential to maintain the integrity of the treated water and to reduce and eliminate episodes of waterborne disease. Risk assessment of the distribution system should be conducted to reveal spots where cross-connections and backflow could occur. Appropriate backflow prevention devices should be placed and maintained on service lines. The Building and Plumbing Codes already specify requirements for backflow prevention devices. The main risk from cross-connection contamination is due to the lack of inspection, testing, and maintenance of these devices. A second risk arises from the lack of comprehensive inventory and management programs for keeping track of the hundreds, thousands, or tens of thousands of backflow prevention devices that are required to protect a drinking water distribution system (N. Carley, personal communication, March 16, 2001). Some municipalities have implemented full cross-connection control programs; however, the majority of municipalities and water suppliers in the province have not.

All water suppliers should develop and implement a formal cross-connection control program to minimize the risk of contamination in the distribution system. An effective cross-connection control program should require the regular inspection, testing, and maintenance of backflow prevention devices. The program should also include a comprehensive inventory and management system to keep track of all backflow prevention devices and the status of these devices.

Individual households should also be wary of the potential for cross-connections and backflow that can contaminate the household water supply. Hoses attached to the house should not be left submerged in swimming pools, puddles, buckets, or other sources of unpotable water. Laundry tubs should not have a hose extending from the taps into a sink full of water. Herbicides and fertilizers that are applied to gardens and yards by a container attached to a garden hose must have a valve that prevents backflow of the chemicals into the water supply and should not be left on an unattended hose.

Industrial customers on water systems should be informed of cross-connection concerns, particularly backflow. There have been numerous instances of contamination of water systems when industrial contaminants and wastewater have been sucked into the local water supply, causing discomfort, illness, and even death (University of Florida, 2001). Industries and large buildings often have internal pumped systems that contain contaminated water for industrial or commercial processes, heating, air conditioning, and other uses. All need well maintained backflow preventers to protect the public water supply.

Operator Training

The Walkerton outbreak was a dramatic and tragic illustration of the need for properly trained water systems operators. The men and women who run the water systems in B.C. and provide water to the public must have a good understanding of water quality issues and the competence maintain the water system and to protect the water from contamination. The lack of knowledge among some small system operators has been identified as a risk factor for drinking water safety. The operators need to know not only how to supply safe water on a day-to-day basis, but also how to respond to sudden source contamination, industrial spills, power outages, equipment failures, water main breaks, chlorine gas leaks, vandalism, and other emergencies that could compromise the quality of the water. They need to have developed emergency response plans. Operators also need to know how to conduct proper water sampling and need to understand the significance of test results.

Training programs and voluntary certification are currently available for operators of medium and large water systems in B.C. The B.C. Ministry of Health Services has been working with the B.C. Water and Waste Association to develop a curriculum for the training and certification of water system operators, particularly for small water systems. This program, along with the production of an operator's manual, will help ensure that all water system operators in B.C. have adequate training and knowledge to provide safe water to the public. We recommend that these training courses become mandatory, including training in source assessment and source water protection planning.

▶ See recommendation 24.

At the Consumer's Tap

Water is not sterile. Even with adequate treatment, some micro-organisms may persist in the water system. For most healthy consumers, with strong immune systems, these do not cause disease. Some consumers with health problems or weak immune systems, however, may want to take extra precautions against waterborne disease by supplementing the treatment that their water provider already undertakes. Newborn babies, for example, should not be fed formula made with tap water; the water used should be boiled first and cooled. People with AIDS or organ transplants may also want to treat their water. In areas of B.C. where there is very little treatment of water, consumers with health problems may want to conduct their own treatment to further protect their water before using the water for drinking. Consumers should be cautious, however, because some water treatment devices are not regulated and may not provide protection from waterborne contaminants, particularly pathogenic microbes.

Boiling Water

Bringing tap water to a rolling boil for one minute is a very effective method of treating water, as it will kill *Cryptosporidium*, *Giardia*, bacteria, and viruses. At elevations greater than 2,000 metres (6,500 ft), water should be boiled for two minutes. This is what should be done by consumers whose water systems have a boil-water advisory. Even when there is no advisory on the water system, some individuals, particularly people with HIV or AIDS, with cancer, or with organ transplants, may decide to routinely boil or treat their water to further protect their health.

Bottled Water

Bottled water can provide an alternative source of drinking water when tap water is not aesthetically pleasing or is subject to a boil-water advisory such as during a waterborne disease outbreak. It is expensive, however, and not practical for cooking, washing or showering.

According to the Canadian Bottled Water Association, demand for bottled water in Canada is increasing by at least 10 per cent a year. Sales were more than 650 million litres in 1999. Bottled water is defined as any water offered for sale in a sealed container. "Mineral" or "Spring" water is obtained from an underground source that is not a public water supply. Mineral water has a larger amount of dissolved mineral salts. Other bottled water comes from any source, such as tap water, that a manufacturer treats by carbonation, microfiltration, ozonation and/or irradiation.

In Canada, pre-packaged water and pre-packaged ice are regulated as a food product by the Canadian Food Inspection Agency. It must be fit for human consumption, free from poisonous or harmful substances, and prepared and stored under sanitary conditions. It should not contain any coliform bacteria, but it is not sterile water, and so heterotrophic bacteria can re-grow if the water is left sitting for long periods.

Bottled water is subjected to periodic tests and sampling, but sampling frequency can range anywhere between once a year to once every three-four years. There have been no recorded outbreaks of waterborne disease from bottled water in Canada, but some foreign brands have been subject to recalls because of concern over chemical contaminants. In other countries where manufacturing standards are not as high as in Canada, bottled water has been linked to outbreaks of cholera and typhoid.

Boiling water is not effective for the removal of all contaminants. If the water is contaminated with chemicals or toxins, such as nitrate, arsenic, lead, uranium, or blue-green algae toxins, boiling increases their concentrations in the remaining water (Jennings and Sneed, 1996).

Other Disinfection Methods

Other, simple methods can be used to help purify water, but note that these are not reliable methods to remove *Giardia* and *Cryptosporidium*.

Household bleach

Unscented household bleach (five per cent chlorine) can be a good disinfectant for viruses and bacteria. Add one drop (0.05 ml) of bleach for every litre of water. Shake, cover, and allow to stand for 30 minutes. Double the amount of bleach for cloudy or cold water or for water taken directly from a lake or stream. A slight chlorine odour should still be noticeable after 30 minutes. If not, you have not added enough bleach. Chlorine tablets can also be purchased from the drugstore or hardware store. This method does not inactivate protozoan cysts and oocysts.

Purification Tablets

Tablets that release iodine may be used safely to purify drinking water. These tablets can be found at most drugstores and sporting goods stores. The names vary, but they are generically known as halazone tablets. Follow the directions on the package. Usually one tablet is sufficient for one litre of water. The dosage is doubled for cloudy water. Ordinary household iodine may be used to purify small quantities of water. Add 10 drops for every litre of water. Mix and allow to stand for 30 minutes. Note that pregnant women should not use iodine tablets or household iodine to purify water, as it may have an adverse effect on the fetus. Iodine to disinfect water should not be used over prolonged periods, can affect the function of the thyroid gland. It does not inactivate protozoan cysts and oocysts.

Home filtration

Some households purchase filtration units that either attach to the faucet or filter water through a pitcher. Although many of these products successfully remove taste and odours, they are not water purification devices unless they are approved as such by a testing agency such as the Canadian Standards Association (CSA) or the National Sanitation Foundation (NSF). A device with the NSF label has been tested by that organization and performs the functions detailed on its label. The names of products that have been tested are listed at the NSF Web site. Users must read the product information very carefully and be cautious about relying on these devices for the purity of their water. The customer should always follow the manufacturer's instructions regarding maintenance and filter replacement.

▶ **See Appendix B for National Sanitation Foundation Web site.**

Home Filtration Pitchers

Many households use store-bought pitchers through which they filter tap water to improve the water's taste and aesthetic qualities. These pitchers remove chlorine residuals, as well as sediment and some chemicals, but they do not remove any bacteria, viruses or parasites. The manufacturer states clearly on the packaging that the pitcher filtration system "is not intended to purify water. Do not use with water that is microbiologically unsafe or of unknown quality without adequate disinfection." The pitchers also need to have their filters changed every two months. Otherwise, bacteria can build up on the filter and contribute to illness.

Point-of-Use and Point-of-Entry Systems

A consumer can use a point-of-use device—a reverse osmosis, UV system or a filter—that attaches to the faucet and removes particles at least one micrometer in diameter. When properly installed, operated, and maintained, point-of-use systems can be an effective means of treating water. The system only treats water emerging from the faucet to which it is attached. Other faucets in the house will be untreated. To treat the water in an entire household, homeowners can purchase a point-of-entry treatment system that attaches to the main water pipe as it enters the house. The main problem with these types of systems, aside from being costly, is that often the homeowner does not spend enough time properly installing and operating the system or is not diligent enough in maintaining the system. This neglect can make the water quality even worse, as pathogens stopped by the filter can accumulate in the filtering mechanism and breakthrough to contaminate the water. Certain types of point-of-use and point-of-entry systems are also rendered inactive during power failures.

Monitoring the Water System

The multiple barrier and HACCP approach discussed on pages 76-78 will help to ensure that the water quality in B.C. remains high from source to tap. Monitoring is part of the HACCP approach and must be in place to confirm water systems are performing as they should. Tests, assessments, and inspections must be conducted with regularity to ensure that hazards are being eliminated and that standards are remaining high.

Under the Safe Drinking Water Regulation, it is up to the medical health officer in each region to establish the testing protocol, frequency, and location of samples. This requirement is fine as it stands. However, adequate staff and financial resources must be available to ensure testing occurs with appropriate frequency. Some large regions, such as the municipalities within the Greater Vancouver area, test almost daily. Other small systems have one test a year or less. It is clear that on the latter type of systems, a waterborne disease outbreak could occur before the hazard is identified and the population warned.

Individuals collecting water samples or making water quality measurements should be trained in proper sample collection and measurement methods, including quality assurance and safety. Testing should be conducted on source water and on the treated water in the distribution system.

Laboratory Testing and Quality Assurance

Unless there is a quality assurance program, laboratory testing can be unreliable and inaccurate. Quality assurance of laboratory testing gives the water provider, regulators, and the public confidence that the results are reliable and accurate. The Safe Drinking Water Regulation requires that water testing be carried out at a microbiology laboratory approved by the Provincial Health Officer. The B.C. Centre for Disease Control manages this accreditation program for the Provincial Health Officer. There should also be an accreditation program for laboratories carrying out chemical tests on water such as that provided by the Canadian Association of Environmental Laboratories (CAEL).

Fortunately in B.C., the Safe Drinking Water Regulation requires that all microbiological test results are routinely sent from the testing laboratory not only to the water provider but also to the regional medical health officer. This ensures that in B.C. we will not have the same problem that arose in Walkerton when the water supplier did not inform the medical health officer of poor test results and inadequate disinfection.

During the last year there has been an increased demand for microbiological testing of drinking water. The laboratory services at the B.C. Centre for Disease Control tests 200-300 water samples a day and at times has tested as many as 700 samples a day (J. Isaac-Renton, personal communication, July 18, 2001). It would be advisable for the B.C. Centre for Disease Control to examine ways of developing the required revenue to support this increased testing—such as by an appropriate fee being charged. It would also be advisable for determining ways of funding the laboratory accredition process.

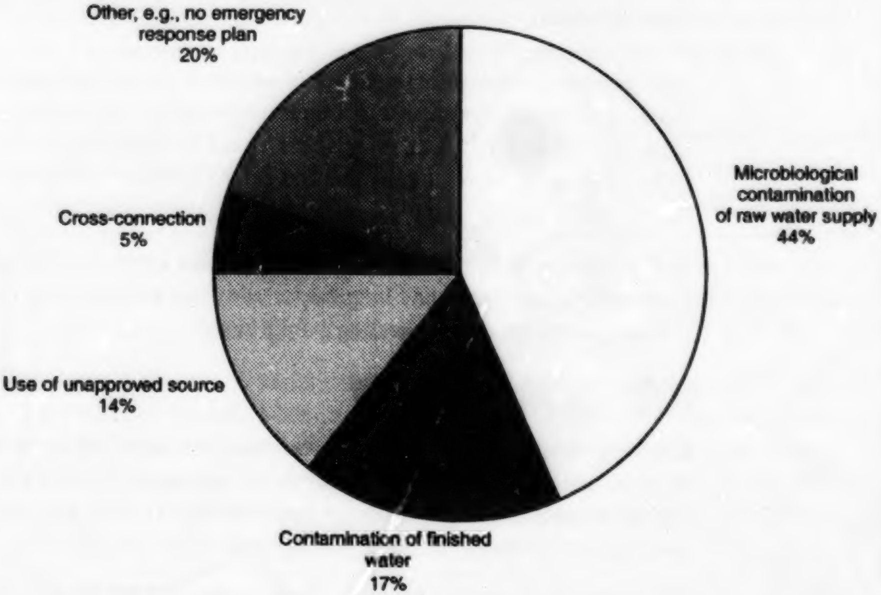
▶ **See recommendations 12 and 21.**

Public Health Inspections

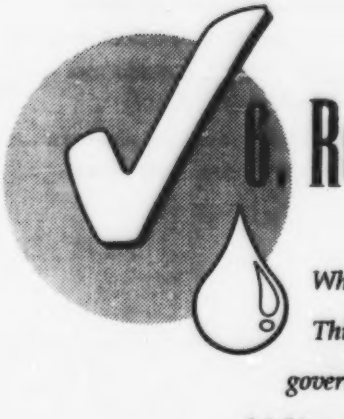
Regular inspections by public health officials are important in ensuring that high standards are maintained and that there is compliance with the Safe Drinking Water Regulation. Regular inspections help to identify unhealthy conditions or practices that, if not corrected, can lead to waterborne disease. On average, 76 "critical hazards" are found each year during inspections conducted by environmental health officers (Figure 9). As shown in Figure 7 (page 39), only one-quarter of water systems receive a routine inspection each year. Additional staff and resources are required, if all water systems are to receive regular inspections.

▶ **See recommendation 12.**

Figure 9: Critical Hazards in B.C. Water Systems, Annual Average, 1989 - 1998



A critical hazard is a health hazard that requires immediate attention. On average, 76 critical hazards are found each year during inspections conducted by Environmental Health Officers. Source: Public Health Protection, B.C. Ministry of Health Services.



6. Recommendations

What can be done to reduce the risk of waterborne illnesses in British Columbia? This chapter outlines 32 specific actions water suppliers, local health officials, government, and other organizations can take to protect and improve the quality of drinking water.

This chapter outlines recommendations aimed at achieving better management of drinking water systems and thus improving water quality in British Columbia. The recommendations are based on analysis by the Provincial Health Officer, along with the findings of province-wide consultations on the Drinking Water Protection Plan (Praxis Pacific, 2001) and extensive consultations involved in developing this report.

As well as supporting many of the initiatives that have already been undertaken, the recommendations set out a blueprint for addressing the most urgent and correctable drinking water problems affecting public health.

Eight Key Messages

Underpinning this report's recommendations are eight key messages related to improving drinking water quality. They reflect the expertise of the Provincial Health Officer, as well as the best evidence from research and the extensive consultations involved in the development of this report.

1. All surface water (water from lakes, creeks, and rivers) is likely to be contaminated. Even the most remote and seemingly untouched water source can be carrying contaminants that may harm human health.
2. The best assurance of safe drinking water at the consumer's tap is a multi-barrier approach. There are four basic barriers that must be in place to ensure that water is safe to drink:
    - At the source – protection of source water quality by limiting or prohibiting wastewater discharges and other sources of water pollution
    - Treatment – adequate treatment such as disinfection and/or filtration
    - During storage and distribution – safeguarding water quality during storage and distribution, and

- At the consumers tap – monitoring of the distribution system and enforcement of standards.

A practical tool to assess and manage these multi-barriers is the use of the Hazard Analysis and Critical Control Points (HACCP) approach. While HACCP is most often applied to food safety, it is a system of risk assessment and management that can be adapted to drinking water safety. It focuses on identifying and addressing the junctures in the system (critical control points) where there may be a hazard and the loss of control that could result in an unacceptable safety risk.

3. Management of the water system should be based on assessment and management of public health risk from source to tap, as well as on end-product testing. A good test result may lull people into thinking there is no risk to the system. In fact, random monitoring of water quality by microbiological or chemical testing cannot in itself ensure water safety and cannot substitute for good risk assessment and risk management. We must anticipate the risks to our drinking water and take steps to prevent them from occurring, rather than hope we catch them in random tests. Good water system management requires a culture of continuous quality improvement.

4. Better protection and management of the land that surrounds the water source will protect and improve the quality of water at the tap. However, there are limits to what such measures can achieve. Pathogens such as *Cryptosporidium* and *Giardia* are inevitably present in B.C. watersheds. It will always be difficult to maintain low turbidity (cloudiness), particularly during times of high rainfall or during the spring snowmelt. Consequently, appropriate water treatment or alternate water supplies must be in place to handle episodes of poorer source water quality.

5. To prevent disease, all surface water requires disinfection. This generally includes the presence of a detectable disinfection residual at the end of the distribution system. Groundwater systems that are subject to microbiological contamination from surface water should also have disinfection. There are some groundwater systems that after careful assessment and testing may be determined to be safe and to not need disinfection.

6. Maintaining safe drinking water will require investments in filtration and other advanced forms of water treatment. Chlorine and other disinfectants kill many of the micro-organisms that cause disease. Unfortunately, these traditional methods of water treatment do not always neutralize hardy parasites such as *Giardia* and *Cryptosporidium*. Additional purification methods are available, and many water suppliers have already enhanced their treatment systems using these newer technologies. The adoption of treatment standards for all B.C. water systems, with a timeline for compliance, will move B.C. along in this direction.

7. Good, accurate information is essential to any decision-making and management. When it comes to B.C.'s water systems, we currently rely on a patchwork of information about disease outbreaks, boil-water advisories, and statistics collected by individual water suppliers and regulatory staff. British Columbia needs a database that reports on the characteristics of all water systems, water system performance, and the occurrence of water-related illnesses.

8. If we want to improve drinking water quality in British Columbia, we will have to find ways to pay for it. Risk assessments and evaluations, improved treatment plants, more manpower for assessment and monitoring—all of these require adequate funding. There are many ways to raise the capital and operating costs needed for improvements and enhancements—taxation, user-pay, or public-private partnerships are examples. Consumers and politicians will need to be aware of the benefits and costs of drinking water improvements, in order to make the best decisions about how water systems should be managed and where the money will come from. Nevertheless, it must be stated that without adequate funding, no improvements can take place.

Blueprint for Action

This chapter contains the 32 specific recommendations to help improve water quality in British Columbia. With each recommendation, we have identified the agency or individual that should take the lead in putting the recommendation into action. Together, the recommendations, grouped into the seven categories, form a blueprint that can be used to focus our efforts on the most urgent and correctable problems that will have the greatest returns in terms of improved public health. If the recommendations are implemented, we can expect to see continued improvement in drinking water quality and a reduction in water-related illness in British Columbia.

Blueprint for Action on Drinking Water Quality

Blueprint category	Recommended actions
1 **Commitment to drinking water quality**	1. Legislated authority*
	2. Size of regulated systems*
	3. New and orphaned water systems
	4. Groundwater
	5. Cross-connection control
	6. Inter-ministry coordination*
	7. Drinking water specialists
	8. First Nations water systems
	9. Standards and guidelines
	10. Microbiological treatment standards*
	11. Fluoridation
	12. Additional resourcing
	13. Access to capital funds
2 **Risk assessment and information gathering**	14. Multiple barriers and critical control points
	15. Hazard identification and risk assessment
	16. Surveillance for waterborne disease
	17. Standardized data-set and provincial database for drinking water quality
3 **Planning for risk management**	18. Risk management plans
	19. Triggering of boil-water advisories
	20. Regional action plans
4 **Quality assurance and good management practice**	21. Laboratory accreditation
	22. Testing of raw water sources
	23. Terms and conditions of operating permits
	24. Operator training and certification
	25. Practice guidelines—local health officials
5 **Public involvement and education**	26. Community involvement
	27. Public education
6 **Accountability**	28. Performance measures*
	29. Public reporting*
7 **Research and evaluation**	30. Watershed and groundwater research
	31. Walkerton Inquiry report
	32. Long-term evaluation of results

* Priority recommendations

1. Commitment to drinking water quality

Legislative authority

Many of the watersheds in the province serve a variety of uses—forestry, mining, agriculture, urban development, and recreation—as well as being a source for drinking water. They require management so that drinking water systems that may be vulnerable to microbiological, physical and chemical contamination are sufficiently protected while allowing for appropriate multiple uses.

> **Recommendation 1** – Ensure that there is legislative authority (such as the *Drinking Water Protection Act*) that gives priority to the safety of drinking water and that covers management of the system from source to tap. **Lead: Ministry of Health Services and Ministry of Water Land and Air Protection.**

Size of regulated systems

British Columbia has three times as many water systems as it did ten years ago. Most of the increase has been among small water systems serving 2 to 14 connections each. It has been suggested that the threshold of regulation be increased to 5, 10 or even 25 connections. While it is true that if British Columbia's 2,000 small systems were de-regulated public health resources would be freed up to focus on large systems, all British Columbians deserve protection from waterborne illness. A workable alternative is to establish different levels of drinking water standards according to the type and size of the water system.

> **Recommendation 2** – (a) Continue to apply drinking water legislation and regulations to all systems with one connection or more that serve more than a single-family dwelling. (b) Study and carry out public consultation on the feasibility of taking an accreditation or graded approach to small water systems (with less than 15 connections), rather than full compliance with legislation. (c) If legislation is amended such that small water systems are subject to less stringent regulatory requirements, provide training for water system owners, so they know how to protect users by ensuring safe drinking water. (d) Provide public awareness and education regarding any changes, as well as some means of informing homeowners of their responsibilities and liabilities.
> **Lead: Ministry of Health Services.**

New and orphaned water systems

There are a large number of small waterworks systems that have no clear ownership or supplier to make needed improvements.

> **Recommendation 3** – (a) Restrict approval of water licenses for new waterworks or extensions of existing waterworks to those that are i) owned and operated by regional districts, municipalities or qualified improvement, irrigation or waterworks districts, or ii) owned by a clearly identified private supplier who has defined responsibilities in

legislation. Lead: Local health officials. (b) Identify in legislation the government body that will assume responsibility for any currently existing "orphaned systems" (waterworks systems lacking a clearly identified owner). **Lead: Provincial government.**

Groundwater

Regulation of groundwater, as recommended by the Auditor General, will enable enforcement (e.g., sealing of abandoned wells) and better tracking of the use of groundwater.

> **Recommendation 4** – Include in legislation the authority to protect groundwater. **Lead: Ministry of Water, Land and Air Protection.**

Cross-connection control

Because of the possibility for a distribution system to be contaminated cross-connection control programs are essential to maintain the integrity of the system. This includes the prevention of cross-connections, backsiphonage, infiltration or uprotected storage facilities and during repairs and construction.

> **Recommendation 5** – Include in legislation the authority to require water suppliers to develop and implement cross-connection control programs to protect the drinking water distribution system.
> **Lead: Ministry of Health Services.**

Inter-ministry coordination

The duties and responsibilities for water quality in the province are split between a number of ministries and agencies. (see Table 2). Clear government accountability, increased cooperation, and coordination are needed.

> **Recommendation 6** – Establish—either through legislation or administrative policy—a lead ministry coordination function, or other coordinating mechanism for water quality issues.
> **Lead: Provincial government.**

Drinking water specialists

Local health authorities are responsible for protecting the public from waterborne illness. Drinking water safety is a high priority for the medical health officers, environmental health officers, and public health engineers employed by health authorities, but these staff have duties that cover a broad range of health and sanitary issues. Creating dedicated positions would help to ensure that drinking water receives the necessary attention.

> **Recommendation 7** – Establish drinking water specialists or equivalent positions in each health region. These positions should be provided with special training and should work as part of the regional team that includes the medical health officer, environmental health officers, and public health engineer. **Lead: Ministry of Health Services and local health authorities.**

First Nations water systems

Water systems for First Nations on reserve fall under the jurisdiction of the local band and the federal government. Many First Nations water systems have not had their plans approved or permits issued by provincial public health officials.

> **Recommendation 8** – Initiate discussions with First Nations and the federal government ministries involved to determine collaborative actions that will enable continued improvements in on-reserve water systems in B.C. **Lead: B.C. Ministry of Health Services.**

Standards and guidelines

The *Guidelines for Canadian Drinking Water Quality* are produced and reviewed periodically by Health Canada in cooperation with representatives from the health and environment ministries of the provinces and territories. How many and which of these guidelines should be mandated as "standards" has been the subject of much discussion. There is a need for expert review into the choice of water quality parameters and water treatment to be prescribed by regulation in British Columbia.

> **Recommendation 9** – Form an expert panel of scientists, regulators, water suppliers, and environmental groups, to meet as required, to review the scientific evidence and the expectations for drinking water quality in British Columbia. This panel would have specific terms of reference and would recommend to the Minister of Health Services specific standards that should be established, whether in new regulations, amendments to current regulations, the *Drinking Water Protection Act*, or practice guidelines. **Lead: Ministry of Health Services and Ministry of Water, Land and Air Protection.**

Microbiological treatment standards

Water treatment is the most effective means of protecting the public from water-related illness. Compared to many other jurisdictions, B.C. has a long history of under-treating its drinking water. Setting and implementing treatment standards (such as required log reductions for each system) would minimize the health risks that British Columbians face from waterborne contaminants.

> **Recommendation 10** – a) Incorporate treatment standards into the operating permits for water systems. b) Set a minimum level of treatment (required log reductions for pathogens found in B.C. waters, particularly *Giardia* and *Cryptosporidium*) to be met by all water treatment systems.c) Develop a consistent set of guidelines for use by medical health officers in deciding when, where, and how much additional treatment may be required for a particular system.
> **Lead: Ministry of Health Services and local health officials.**

Fluoridation

The addition of fluoride to drinking water helps to protect children and adults from tooth decay. For maximum protection of teeth, a fluoride level of 0.8 mg/L is recommended by the Canadian Dental Association, Health Canada and the College of Dental Surgeons of BC. British Columbia has the lowest rate of fluoridation of water supplies in Canada.

> **Recommendation 11** – Increase fluoridation of community water supplies to a level of 0.8 mg/L so that more British Columbians receive the benefits from community water fluoridation. **Lead: Ministry of Health Services, municipalities and water suppliers.**

Additional resourcing

The eight key messages (page 100) indicate that there is a need for more resources—to carry out assessments, to increase monitoring, for laboratory analyses, for enforcement of the Safe Drinking Water Regulation, for improved treatment, for the development of a water system database etc. All these anticipated improvements will require increased funding. The larger utilities have already found ways of increasing the resources—mainly through increasing the water rates. It is the smaller water systems who have the greatest difficulty in accessing resources.

> **Recommendation 12** – a) Increase funding for assessment and monitoring and for infrastructure improvements to deal with identified risks to public health. b) Explore different methods of funding—increased user fees, fees for laboratory testing currently being provided by the laboratory services of the B.C. Centre for Disease Control c) Ensure that the needs of small water systems are given priority. **Lead: Health Authorities, Ministry of Health Services, Ministry of Water, Land and Air Protection and Ministry of Community, Aboriginal, and Women's Services.**

Access to capital funds

Small water systems, particularly those operated by Improvement Districts, do not currently have access to tax-supported, cost-shared capital funding for water system improvements.

> **Recommendation 13** – Incorporate improvement districts into regional districts in order to give access to funds for capital works. **Lead: Ministry of Community, Aboriginal, and Women's Services.**

2. Risk assessment and information gathering

Multiple barriers and critical control points

Achieving safe water requires a focus on the entire water system—from source to tap. This means identifying the critical points where the water system is vulnerable to chemical, physical or microbiological contamination, so that protective barriers can be put in place. There is currently no standardized process for assessing B.C.'s water systems from source to tap.

> **Recommendation 14** – Develop a made-in-B.C. hazard identification, risk assessment and risk management tool, similar to the Hazard Analysis and Critical Control Points (HACCP) approach. **Lead: Ministry of Health Services in collaboration with the Ministry of Water, Land and Air Protection.**

Hazard identification and risk assessment

A hazard identification and risk assessment for each water system will enable system operators and health officials to understand the characteristics of their water systems and to deal with the most prevalent and pressing risks first.

> **Recommendation 15** – In collaboration with water system operators conduct site-specific hazard identification and risk assessment on all water systems in B.C. using the approach in recommendation 14. Financial and practical assistance should be made available to small system operators and health officials. **Lead: Local health officials (medical health officers, environmental health officers, public health engineers) and Ministry of Health Services.**

Surveillance for waterborne disease

The extent of enteric (intestinal) illnesses is not known precisely, as many cases are not recognized or reported. For most of the cases reported, we lack information about the source of the infection (water, food, or other means) and whether the illness was acquired in B.C. or while travelling outside of the province. The B.C. Centre for Disease Control is researching improved methods of surveillance for waterborne illness to determine if more rapid detection of outbreaks or identification of the ongoing prevalence of waterborne illness in the population is feasible.

> **Recommendation 16** – Continue to improve British Columbia's capabilities to (a) monitor the occurrence and causes of waterborne illness, and (b) rapidly detect any occurrence of waterborne illness. **Lead: B.C. Centre for Disease Control and Prevention and local health authorities.**

Standardized data-set and provincial database for drinking water quality

Currently there are multiple, fragmented information systems for water systems. These have been established with local health officials, with some of the large water suppliers, in laboratories carrying out testing, in the Ministry of Health Services, in the Ministry of Water, Land and Air Protection and in other ministries. In order to perform standardized risk assessments, water suppliers and public health officials need to work from a common framework for data collection. Appendix E outlines a proposed data-set for assessing drinking water systems in British Columbia, developed in consultation with medical health officers, environmental health officers, public health engineers, and staff from several ministries.

Recommendation 17 – (a) Adopt a standardized data-set and tools for gathering risk assessment information. (b) Use the data-set to conduct an inventory of all water systems in B.C., and create a centralized, integrated information data base on B.C. water systems. (c) Develop a long-term plan so that a province-wide, integrated information system is developed over the next five years. (d) Use the resulting information to support the management of all water systems, to set standards and guidelines and to generate public reports. **Lead: Ministry of Health Services, Ministry of Water, Land and Air Protection, and local health authorities.**

3. Planning for risk management

Risk management plans

Armed with an analysis of potential hazards and a risk assessment for a water system and information from ongoing monitoring of water quality, suppliers and planners will be better able to manage risks to the water system. Using an approach similar to HACCP they will be able to develop strategies to minimize and control potential contamination from the identified control points and to intervene should contamination be detected.

Recommendation 18 – Require suppliers to draw up a risk management plan for approval by medical health officers. Plans should address the hazards identified by the risk assessment, using the multiple barriers and HACCP approach. The drinking water specialist should assist suppliers who need help in doing the risk management plan. **Lead: Water suppliers, in collaboration with local health officials.**

Triggering of boil-water advisories

Some, but not all, jurisdictions have established management plans that trigger automatic boil-water advisories when monitoring shows elevated levels of certain parameters. The Ministry of Health Services has developed a guideline on boil-water advisories.

Recommendation 19 – Ensure as per the Safe Drinking Water Regulation that automatic triggering of boil-water advisories is in all emergency plans. **Lead: Water suppliers, in collaboration with local health officials.**

Regional action plans

Prevention of waterborne disease requires proactive planning on the part of water suppliers and responsible public authorities alike.

Recommendation 20 – Require local health authorities to develop and publish a regularly updated action plan for continued improvement of all water systems within their region. This action plan should be created with input from local health officials and other government officials who have responsibility for water. The action plan for each region should be reported to the municipal council, the regulatory ministries, and the public. **Lead: Local health authorities.**

4. Quality assurance and good management practice

Laboratory accreditation

The usefulness of laboratory testing depends on an effective quality assurance program to ensure accuracy and reliability. This will include protocols covering the collection and transportation of samples to avoid contamination.

> **Recommendation 21** – (a) Continue to require that all microbiological samples be processed at a laboratory approved by the Provincial Health Officer. **Lead: Provincial Health Officer.** (b) Require that a suitably trained technician carry out tests that are designed to be performed in the local community (such as the Colilert test for *E. coli*). **Lead: Provincial Health Officer, with assistance from the B.C. Centre for Disease Control.**

Testing of raw water sources

Problems have occurred when unexpected contaminants have been found *after* water sources were approved. Prior testing for potential contaminants enables either the development of appropriate treatment or the choice of alternate sources of water.

> **Recommendation 22** – Require that all proposed water sources undergo relevant chemical, physical, and microbiological analysis prior to approval as community water supplies. **Lead: Local health officials.**

Terms and conditions of operating permits

In some parts of the province, health officials are placing terms and conditions on the permit that is required to operate a water system under the B.C. Safe Drinking Water Regulation. Such conditions, which were envisaged when the regulation was developed in 1992, contribute to the improvement of drinking water quality.

> **Recommendation 23** – (a) Develop guidelines for standardized terms and conditions for issuing an operating permit for a community water system. (b) Include in permits the requirements for treatment outcomes (see recommendation 10, Treatment Standards).
> **Lead: Ministry of Health Services and local health officials.**

Operator training and certification

Operators of small water systems may lack the knowledge and training required to maintain safe drinking water. The Ministry of Health Services has been working with the B.C. Water and Waste Association and the Environmental Operator Certification Program to develop a curriculum to train and certify water system operators. Recently 50 small system operators have been trained and certified and 29 courses are scheduled to take place throughout the province this fall. This program should be made mandatory, using the Environmental Operators' Certification Program to classify the water systems and the level of certification required.

Recommendation 24 – Continue to provide training and certification for water system operators and make this mandatory, with subsidies to enable the participation of operators of small systems. **Lead: B.C. Water and Waste Association, in collaboration with the Ministry of Health Services and the Environmental Operators' Certification Program.**

Practice guidelines—local health officials

Scientific knowledge and technology are constantly changing. Practice guidelines—kept current and based on best world practice—help professionals make their work more effective and more uniform. The Council of Public Health Engineers of B.C. has developed a practice guideline to assist consulting engineers to know the requirements for approval of a water treatment system in British Columbia. Medical health officers and environmental health officers should consider developing similar practice guidelines for risk assessments, compliance monitoring, enforcement, and other topics related to drinking water policy and legislation.

Recommendation 25 – Develop practice guidelines to encourage medical health officers, environmental health officers, and public health engineers to follow a standardized approach to applying the Safe Drinking Water Regulation and *Drinking Water Protection Act*. Practice guidelines should draw on the expertise of other health officials, be updated regularly, and be monitored to ensure that they are consistently applied. **Lead: Health Officers Council, Council of Chief Environmental Health Officers, Council of Public Health Engineers of B.C., and Ministry of Health Services.**

5. Public involvement and education

Community involvement

From a health standpoint, it is clear that British Columbia should be taking additional steps to protect the public from waterborne illness. However, the decision to spend money on filtration systems or other improvements will ultimately be made by community members and their elected representatives. Consumers need to be aware of the risks, benefits, and costs of additional protection, so that they can make the best possible decisions about how their water supplies should be managed.

Recommendation 26 – Develop information and tools to help communities make decisions about upgrading their water systems—before problems occur. **Lead: Ministry of Health Services, in collaboration with local health officials.**

Public education

Members of the public can play an important part in maintaining the safety of the water supply if they receive accurate and accessible information. In particular, people drawing their water from unregulated sources where there is only one connection (single-family dwellings on wells, individually piped sources, etc.) can benefit from the materials available from their local public health office.

Recommendation 27 – Increase the promotion of existing public education workshops and materials (publications, videos, tool kits) that are already available. Develop more public education materials on water quality issues, such as source protection, to inform the public about what they can do to protect their drinking water. **Lead: B.C. Water and Waste Association, in collaboration with local health officials, the Ministry of Health Services, and the Ministry of Water, Land and Air Protection.**

6. Accountability

Performance measures

The number of waterborne disease outbreaks, contacts with the health care system for intestinal diseases, and an annual count of boil-water advisories are some of the performance measures we have available. These measures are useful, but they have limitations in terms of completeness and timeliness. We do not at present know, for example, how many systems treat their surface water, and how many simply deliver untreated water to consumers. How many log reductions does each system achieve in its treatment against *Giardia* and *Cryptosporidium*? How many systems have personnel who have undergone operator-training certification? These are some of the important data elements we should know. An expanded, standard set of measures —and methods to collect the needed information—would assist in gauging our success in protecting the quality of drinking water. The proposed data-set (Appendix E) provides the required data elements for several potential performance measures.

Recommendation 28 – From a standardized data-set and the recommended provincial database for drinking water quality (see recommendation 17), establish a smaller set of key measures to be used for reporting on the quality of British Columbia's drinking water and the performance of drinking water systems.
Lead: Ministry of Health Services, Ministry of Water, Land and Air Protection, and Ministry of Sustainable Resource Management.

Public reporting

The public has the right to know the results of monitoring their water supply. Dissemination of this information, a requirement for true public accountability for water management, has become the common practice in other jurisdictions. It is already being made available by some of the larger suppliers and health regions in B.C. (See: Capital Region, Greater Vancouver and Fraser Valley web sites—Appendix B). The Safe Drinking Water Regulation requires public notification of test results on the regulated microbiological contaminants and of other monitoring results. Some water purveyors do this, however, only on a specific request by a member of the general public, if for example a citizen happens to call and ask for the results. Publicly available reports produced from this information would improve accountability.

> **Recommendation 29** – (a) Provide the public regularly with results of chemical, physical, and microbiological monitoring of their drinking water supply and with an interpretation of the health significance of these results, with the assistance of the medical health officer. **Lead: Water suppliers.** (b) Make regional information on water quality and water systems (see recommendation 28) available to both professionals and interested members of the public, including information on what to do during boil-water advisories. **Lead: Local health authorities.**

7. Research and evaluation

Watershed and groundwater research

To ensure that monitoring and quality control of water systems continue to improve, research must continue in a number of areas. Page 83 of this report identifies some suggested research questions.

> **Recommendation 30** – Carry out further research into public health impacts of watersheds and groundwater sources.
> **Lead: Ministry of Water, Land and Air Protection.**

Walkerton Inquiry Report

At the time of publishing this report, the inquiry continues into the outbreak of waterborne *E.coli* O157:H7 infection in Walkerton Ontario. The inquiry has carried out a comprehensive review of both scientific issues and standards, and its final report, expected in the spring of 2002, will merit close attention by other jurisdictions. (see Appendix B for web site, including background documents presented to the inquiry).

> **Recommendation 31** – Review the implications of the final report of the Walkerton inquiry for improving the quality of drinking water in B.C.
> **Lead: Provincial Health Officer.**

Long-term evaluation of results

Drinking water legislation, policies, and programs should be reviewed on a regular basis to ensure that they remain appropriate and effective.

> **Recommendation 32** – Establish a mechanism to assess the long-term effectiveness of British Columbia's drinking water activities and evaluate the need for changes to be made. **Lead: Ministry of Health Services and Ministry of Water, Land and Air Protection.**

Appendix A
Acknowledgments

Many individuals contributed to the preparation of this year's annual report. Dr. Shaun Peck, Deputy Provincial Health Officer, led the development of the report and carried out widespread consultations over a two year period. Medical health officers, environmental health officers, public health engineers, water system operators, ministry staff, and other drinking water experts provided content and suggestions and reviewed various drafts of the report. Other individuals and groups provided data and technical support. The Provincial Health Officer gratefully acknowledges all contributors for their support and assistance.

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Appendix B

Internet Resources

American Water Works Association
http://www.awwa.org/

Australia
A Preventive Strategy from Catchment to Consumer
http://www.health.gov.au/nhmrc/advice/pdf/waterqly.pdf

B.C. Center for Disease Control (BCCDC)
BC Centre for Disease Control (BCCDC) is British Columbia's Centre of Excellence for the prevention, detection and control of communicable disease, and a provider of speciality health support and resource services. Five key integrated divisions within BCCDC provide the coordinated services essential to efficiently and effectively prevent and control communicable disease in the province. These are: Epidemiology Services, Laboratory Services, STD/AIDS Control, Tuberculosis Control and BC Hepatitis Services.
http://www.bccdc.org/index.shtml

B.C. Drinking Water Protection Act
http://www.legis.gov.bc.ca/2001/3rd_read/gov20-3.htm

B.C. Government
This site provides access to a description of all B.C. Government ministries and their responsibilities.
http://www.gov.bc.ca/bcgov/popt/orgs/

B.C. Legislation
This site provides access to all legislation affecting drinking water in B.C.
http://www.legis.gov.bc.ca/legislation/index.htm

B.C. Ministry of Health Services: Health Files

- Blue Green Algae. #47 June 1995
- *Campylobacter* infection. #58 March 1997
- Cryptosporidiosis. #48 February 2000
- Fluoridation facts #28. December 1999
- *Giardia*sis ("Beaver Fever"). #10 February 2000
- Nitrate contamination in well water. #5 February 2000
- Salmonellosis. #17 February 2000
- Should I get my well water tested? #45 June 1995
- Waterborne diseases in BC. #49 February 2000
- Weakened immune system and waterborne infection. #56 February 2000
- Why should I disinfect my drinking water? #49b February 2000

http://www.healthservices.gov.bc.ca/hlthfile/

B.C. Ministry of Health Services
Public Health Protection, Drinking Water Program
http://www.healthservices.gov.bc.ca/protect/water.html

B.C. Ministry of Water, Land and Air Protection Protection,
Water Resource Information
http://www.elp.gov.bc.ca/wat/

B.C. Safe Drinking Water Regulation
http://www.qp.gov.bc.ca/statreg/reg/H/Health/230_92.htm

B.C. Water & Waste Association
http://www.bcwwa.org

Capital Regional District Water Department (B.C.)
http://www.crd.bc.ca/water/

Centers for Disease Control (U.S.)
Information on waterborne infectious diseases.
http://www.cdc.gov./ncidod/diseases/list_waterborne.htm

Centers for Disease Control (U.S.)
Recommendations for using fluoride to prevent and control dental caries in the United States—MMWR Report August 17,2001/Vol.50/No.RR-14.
http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5014a1.htm
http://www.cdc.gov/mmwr/pdf/rr/rr5014.pdf

Drinking Water Outbreaks
Source of international information on drinking water outbreaks maintained by Drexel University.
http://water.sesep.drexel.edu/outbreaks/

Fraser Valley Health Region
Information about current boil-water advisories and beach closures.
http://www.healthspace.ca/fvhr

Greater Vancouver Regional District Water System
http://www.gvrd.bc.ca/services/water/

Hazard Analysis and Critical Control Points
U.S. Food and Drug Administration.
http://vm.cfsan.fda.gov/~lrd/haccp.html

Health Canada, Guidelines for Canadian Drinking Water Quality
http://www.hc-sc.gc.ca/ehp/ehd/catalogue/bch_pubs/dwgsup_doc/dwgsup_doc.htm

Health Canada, Water Quality Activities
http://www.hc-sc.gc.ca/ehp/ehd/bch/water_quality.htm

National Drinking Water Clearinghouse (U.S.)
http://www.nesc.wvu.edu/ndwc/ndwc_index.htm

National Sanitation Foundation (NSF)
The NSF is an independent, not for profit organization that develops national standards. NSF is a Collaborating Center of the World Health Organization (WHO) both for Food Safety and for Drinking Water Safety and Treatment.
http://www.nsf.org/

Newfoundland Department of Environment
Boil Water Advisories for the Province.
Drinking Water Quality Data.
THM Summary for Public Water Supplies in Newfoundland & Labrador.
http://www.gov.nf.ca/env/env/water_resources.asp

Office of the Provincial Health Officer
http://www.healthplanning.gov.bc.ca/pho/

Ontario Ministry of the Environment
Adverse Water Quality Incidents Report.
http://www.ene.gov.on.ca/envision/adverse/adversewater.htm

QualServe
A voluntary, continuous quality improvement program offered by the American Water works Association (AWWA) and Water Environment Federation (WEF).
http://www.awwa.org/qualserve

Quebec Ministere de l'Environnement
Profile of Drinking Water—Data sheets.
http://www.menv.gouv.qc.ca/eau/potable/index-en.htm

Safe Water From Every Tap:
Improving Water Service to Small Communities
(U.S. National Research Council publication)
http://www.nap.edu/catalog/5291.html

Small Water Systems Website
Virginia Interactive Technology Assistance Network (VAITAN)
http://www.vwrrc.vt.edu/sws/

U.S. Environmental Protection Agency, Office of Water
The *Safe Drinking Water Act*.
http://www.epa.gov/safewater/sdwa/sdwa.html
Factoids: Drinking water and ground water statistics for 2000.
http://www.epa.gov/safewater/data/00factoids.pdf

Water Online
http://www.wateronline.com

Water Supply Association of British Columbia
(Formerly the Association of B.C. Irrigation Districts)
http://www.wsabc.com

Walkerton Inquiry
http://www.walkertoninquiry.com

Water Quality Information Center, U.S. National Agricultural Library
http://www.nal.usda.gov/wqic/

World Health Organization, Water and Sanitation
http://www.who.int/water_sanitation_health/

Appendix C
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Appendix D
Waterworks Improvements in the 1990s

[illegible] 1991-1999

Community	Cost	Funding	Project
Penticton	$17,416,300	[2]	Water filtration
Fort St. John	$11,413,430	[2]	New well supply to replace Charlie Lake
Revelstoke	$6,500,000	[1]	Water quality improvement program—filtration of Greely Creek source
Trail	$3,800,000	[2]	Water filtration
Port Hardy	$3,700,000	[1]	Construct water treatment plant
Rossland	$3,623,000	[2]	Slow sand filtration and other improvements
Fort Nelson	$2,500,000	[2]	Water filtration
Enderby	$2,215,000	[2]	River intake and filtration
Merritt	$2,083,158	[2]	New supply/works for Collettville
Chetwynd	$2,016,000	[2]	Water filtration
Kimberley	$1,972,933	[1]	Recreation land infrastructure
Cranbrook	$1,948,000	[3]	Gold Creek pipeline replacement
New Hazelton	$1,763,835	[1]	Water supply and water treatment—joint project with the Hagwilget First Nation
Fruitvale	$1,587,000	[1]	Beaver Valley Water Management area—slow sand filtration water treatment plant
Squamish-Lillooet	$1,500,000	[1]	Pemberton North water system pipe replacement
108 Mile House	$1,235,900	[2]	New supply wells
Hazelton	$1,200,000	[2]	Slow sand filtration—joint project with Gitanmaax First Nation
Williams Lake	$1,074,000	[1]	South Lakeside—water and sanitary sewer extension: top up amount from restructure
Olalla	$1,055,003	[2]	New well source, reservoir, and other improvements
Dawson Creek	$1,027,000	[1]	Arras pumphouse upgrade
Abbotsford	$1,000,000	[1]	Water interconnection to East Abbotsford—design, supply and install 1400 metres of 450mm watermain, pressure reducing station etc. along McMillan Rd between Old Clayburn Rd. and Old Yale Rd.
Radium Hot Springs	$950,000	[1]	Water treatment facility
Kaslo	$945,000	[2]	Treatment—filtration plant
Pemberton	$907,002	[1]	Pemberton water system improvements—new storage and supply works
Port Coquitlam	$750,000	[1]	Cast iron watermain replacement program
Penticton	$700,000	[1]	Upgrade raw water intake—Okanagan Lake

Community	Cost	Funding	Project
Masset	$774,000	[2]	Treatment plant—filtration for manganese
Cove Bay	$729,850	[2]	New supply replacing arsenic wells
Fort Nelson	$711,970	[1]	Raw water line
North Cowichan	$700,000	[1]	Crofton water supply (Crofton pulp mill source)
Grindrod	$650,000	[2]	New system with filtration
Taylor	$570,000	[1]	Water intake improvement—replacing failed infiltration gallery with vertical well system
Nelson	$503,300	[1]	Five Mile Creek water supply (disinfection of city's potable water source)
			chlorination contact time components
Slocan	$500,000	[1]	Water treatment
Rossland	$493,000	[1]	Phase 2 and 3—Blue Eye Swamp raw water diversion
North Okanagan	$485,000	[1]	Haddo Lade Dam Spillway upgrade (North Okanagan Water Authority)
Moyie	$461,890	[2]	New well and system upgrade
Rossland	$403,000	[1]	Phase 1—Hanna Creek intake upgrade and Blue Eye Swamp water diversion
Golden	$380,000	[1]	Northeast Reservoir
Wells	$377,800	[1]	Water reservoir replacement
Kitimat-Stikine	$357,186	[1]	Churchill Drive safe drinking water (revised)
Black Pines	$350,200	[2]	Waterworks upgrade
Ashcroft	$350,000	[1]	Current capacity problems—infiltration gallery
Lions Bay	$275,000	[3]	Brunswick Beach Improvement district water supply improvements (water replacement component)
Fraser Valley	$265,000	[1]	Deroch Water System—replacing water supply
Port Alberni	$260,760	[1]	Sahara Heights water service extension
Nelson	$259,700	[3]	Five Mile Creek water supply (disinfection of city's potable water source) relining existing settling basin component.
Capital	$240,000	[1]	Port Renfrew replacement water reservoir
Qualicum Beach	$230,300	[1]	Design and construction of River Wells #6 and #7—drilling, developing, wellhead construction, power supply and connecting supply mains
Chetwynd	$150,000	[1]	SCADA system upgrading
Port Hardy	$132,652	[2]	Chlorination, pH adjustment
Eagle Bay	$115,514	[2]	Waterworks upgrade
Osoyoos	$114,000	[1]	Lacey Point water connection
Clinton	$97,500	[1]	Retention tank for chlorination facility
Lytton	$86,926	[1]	Ponderosa Heights water line
Rossland	$70,000	[1]	Replace pressure reducing stations
Sayward	$45,000	[1]	Chlorination building—replace temporary building constructed in 1990
Osoyoos	$37,000	[1]	Sunnyville water connection
North Vancouver District	$30,800	[1]	Watermain cleaning flushwater treatment
Port Clements	$29,115	[2]	New ozonator (no longer in service)
Logan Lake	$15,855	[1]	Replacement of main water system pump and motor
Valemount	$10,000	[1]	Safe drinking water improvements—chlorination equipment relocation
Barriere	*	[2]	New wells to replace river supply
Blue River	*	[2]	New well to replace creek supply
Total	$[illegible],222,[illegible]		

* Figures not available.

Grants are available to assist local governments in making improvements to their water systems. Funding sources for the above improvements: [1] 50 per cent funding provided by the Ministry of Municipal Affairs. [2] Either 50 per cent funding through the Grant Program or 2/3 funding under the Federal-Provincial Grant program. [3] 25 per cent funded through Ministry of Municipal Affairs grant program. Data source: B.C. Ministry of Community, Aboriginal and Women's Services (formerly B.C. Ministry of Municipal Affairs). Provided by: Public Health Protection, B.C. Ministry of Health Services.

Type of Improvement	Description	North	Okanagan	[illegible]	Kootenay	Vancouver Island	Fraser Valley	Lower Mainland	Total
New well source	New supply added to existing waterworks to increase supply or to provide for back-up source in case of emergency.	6	1	6	1	0	3	0	17
Intake works	Improvements to existing intake structures to increase depth of intake.	2	7	4	6	2	2	1	24
Surface to deep well	Change from existing surface supply, spring, or shallow well to a deep well, typically a higher quality source.	1	3	7	0	4	1	4	20
Groundwater source improvements	Improvements to wells, well casing, pumps, pumphouses.	6	0	0	0	0	3	0	9
Chlorination	Addition of new chlorination system (sodium hypochlorite, chlorine gas) to existing waterworks system.	7	18	16	7	31	3	4	86
Chlorination improvements	Improvements to existing chlorination system to improve disinfection and/or obtain a chlorine residual in the distribution system.	0	7	4	1	2	3	0	17
UV	Used in both surface water and groundwater sources. Most common in small (2-14 connections) and medium (15-300 connections) water supplies.	2	6	6	2	16	0	0	32
Ozone	Two new plants being constructed in Greater Vancouver Water District at Capilano and Cleveland dam. Technology currently being evaluated by other larger systems.	0	0	0	0	1	0	2	3
Reverse osmosis	Upcoming technology.	1	0	0	0	0	0	1	2
Other disinfection	Other disinfection improvements; type not specified in data collection.	3	3	2	5	4	1	0	18
Filtration	Filtration improvements, such as slow sand and rapid sand filtration.	3	4	8	4	4	0	0	23
Storage reservoirs	Construction of new reservoirs to increase storage capacity. New or improved contact chambers that allow for better/adequate contact time with chlorine prior to distribution.	8	8	11	2	6	13	1	49
Rechlorination	Booster stations to add chlorine to distribution system to ensure a chlorine residual at the ends of supply lines.	0	2	0	0	0	1	2	5
Distribution system	Upgrades to watermains and other piping; pH control for corrosion control and reduction of lead in the drinking water at the tap.	2	2	0	1	0	0	1	6
	Total number of improvements	41	61	64	29	70	30	16	311

Source: Public Health Protection, B.C. Ministry of Health Services, based on data provided by local health authorities.

Appendix E

Proposed Data-Set for Drinking Water Systems

This proposed data-set outlines some of the data required to assess drinking water systems in British Columbia. The list was initially developed at a September 14, 2000 workshop attended by drinking water experts from several local health authorities and from the provincial ministries who are now called Ministry of Health Services and Ministry of Water, Land and Air Protection.

The data-set is a draft, and as such, it requires further discussion and refinement. Once there is consensus on the data requirements, the data-set can provide a check-list for organizations that are developing data collection and reporting systems.

The *Public Health Data Requirements Project* is also examining data requirements, for those data that the Ministry of Health Services requires from health authorities on a regular basis. Data definitions and technical information are available from the Public Health Protection Branch, B.C. Ministry of Health Services.

Water System Characteristics

Item Name	Item Description	Comments
Name	Descriptive name of the waterworks system.	Legal name or name assigned by health authority.
Identifiers	Unique identifiers for the waterworks system. - identifier assigned by health authority - well number - water license number	Each water system will have more than one identifier, assigned by the local health authority and by the Ministry of Water, Land and Air Protection.
Water system type	Type (size) of the waterworks system, based on the number of connections to it.	Code and number of connections: NCG – Greater than 20,000 NC20K – 10,001 to 20,000 NC10K – 301 to 10,000 NC300 – 15 to 300 NC14 – 2 to 14 NC1 – One connection (Codes not finalized)
System initiation	The date the system was first up and running.	

Item Name	Item Description	Comments
Location	The location of the waterworks system. - latitude & longitude of intake sources - areas served (municipalities) - Local Health Area	Ministry of Water, Land and Air Protection identifier provides the geographic position (latitude and longitude).
Ownership type	The legal status of the system's owner (municipality, corporation, private, improvement district etc.).	Code descriptions: ID – Improvement district MU – Municipality NO – No owner PB – Private business PI – Private individual RD – Regional district SO – Society ST – Strata UT – Utility WU – Water users community
Population served	An estimate of the population served by the waterworks system. - Permanent - Transient (maximum in the short term)	A range.
Permit conditions	Any conditions listed on the permit to operate.	Text.
Boil-water advisories	A record of boil-water advisories issued by the health authority. - date issued - date rescinded - reason for the advisory	This information will be used to track trends and current status with regard to the number of boil-water advisories.
Other advisories	Any other advisories issued by other stakeholders such as the supplier, e.g., taste, odour, major contamination.	
At-risk population	Some way of identifying the high-risk or high-density facilities/premises served by the waterworks system, e.g., schools, hospitals, restaurants, etc.	Definition needs to be developed.
Hazard rating	The estimated degree of health risk in a waterworks system. The rating is assigned by an environmental health officer, based on inspection findings and enumeration of health hazards. - high, moderate, low	Definition needs review.
Critical hazards	The number of critical hazards found when inspections are conducted by environmental health officers.	Critical hazards are health hazards that require immediate attention. Eleven categories have been defined. See critical hazards categories 301-311, Water Report , Communicable Disease Control, Health Form HLTH 155.
Risk assessment	Has there been an overall hazard identification and risk assessment of the water-works system, including watershed, storage, treatment, distribution, etc.? - yes/no - date of assessment	A standard risk assessment is under development.
General comments	Any other general comments by the medical health officer, environmental health officer, or public health engineer relevant to the waterworks system.	Text.

Water Sources

Item Name	Item Description	Comments
Water source type	The type of sources or alternate sources for a waterworks system.	Codes and descriptions: GW – Groundwater SW – Surface water CO – Combined SWD – saltwater desalination DGW – deep groundwater SGW – shallow groundwater
Common Name	The names for the sources or alternate sources for the waterworks systems.	Include aquifers. Ministry of Environment, Lands and Parks has names and identifiers for water intakes.
Location	The location of each source.	Ministry of Environment, Lands and Parks links will give latitude and longitude.
Watershed Protection Plans	Is there a watershed protection plan in place for this source? - yes/no	Plans are under development by the Ministry of Water, Land and Air Protection.
Well or aquifer protection plans	Is there a well or aquifer protection plan in place? - yes/no	A Well Protection Toolkit is available to assist individuals and communities in developing, implementing, and monitoring a well protection plan.
Delineation of source (watershed, capture zone)	Is the source mapped? - yes/no - description of where to access maps (text)	The Ministry of Water, Land and Air Protection has maps.
Vulnerability of aquifer rating	A rating of the vulnerability of the aquifer to contamination. - high, moderate, low	Available from Ministry of Water, Land and Air Protection.
Watershed survey	Has a watershed survey been done? - Yes/no What were the results?	Two surveys are being developed: one for a quick assessment and another to be used for thorough planning.
Min. of Water, Land and Air Protection GOAT (Geographical Oracle Access Tool) reference	Spatial display of geographic location.	If the latitude, longitude, and the Environmental Monitoring System (EMS) number are available, then data can be displayed via the Ministry of Water, Land and Air Protection's geographic information system.
Quality of source water—how measured	Where was the sample taken? How was the quality of the water source measured? What were the results?	Three text fields. Include those exceeding Guidelines for Canadian Drinking Water Quality.
Sources Comments	Any other comments by the medical health officer, environmental health officer, or public health engineer relevant to the source(s).	Text.

[illegible]

Item Name	Item Description	Comments
Filtration processes	What processes are used to remove suspended and dissolved solids, including organisms and pathogens, from water by using such media as sand, diatomaceous earth and membranes? Were filtration process improvements made to the system? - Date and nature of improvements	Codes and descriptions: RSF – Rapid sand filtration SSF – Slow sand filtration PF – Pressure filtration MF – Microfiltration UF – Ultrafiltration RO – Reverse osmosis ED – Electrodialysis EDR – Electrodialysis reversal OT – Other filtration processes
Chemical removal processes	What processes are used to remove substances or alter characteristics of drinking water? Were chemical removal process improvements made to the system? - Date and nature of improvements	Code descriptions: AO – a process to remove chemicals on the AO list (GCDWG); MAC – a process to remove chemicals on the IMAC or MAC list (GCDWG); BO – both AO and MAC; OT – a process to remove chemical(s) not listed above; FL – flocculation CG – coagulation.
Other water treatment processes	What other processes are used to treat the water supply so that it meets the water quality requirements of the Safe Drinking Water Regulation and of the medical health office and is not captured by the filtration, chemical removal, or disinfection codes? Were other water treatment process improvements made to the system? - Date and nature of improvements	Codes and descriptions: FL – Fluoridation OT – Treatments not identified in disinfection, filtration, or chemical removal processes. SE – Sequestering (iron, manganese)
Disinfection processes	What processes are used to kill or inactivate organisms which are infectious or injurious to human health? Were disinfection process improvements made to the system? What are the levels of disinfection by-products? What is measured and how often?	Code and descriptions: CA – Chloramination CL – Chlorination O3 – Ozonation OT – Other disinfection processes UV – Ultraviolet
Treatment Comments	How many log reductions does treatment provide against virus, Giardia, and Cryptusporidium? Does the medical health officer consider this adequate? Any other comments by the medical health officer, environmental health officer, or public health engineer relevant to the treatment train.	Text.

Distribution

Item Name	Item Description	Comments
System assessment	Has the distribution system been assessed? - Yes/no - Date Was a standardized approach used? - Yes/no	A standard assessment is under development.
Distribution system characteristics	Type: Pumped, gravity fed. Description of pipe materials, size, lengths, age. Distribution of piping arrangements. Location of secondary disinfection systems.	
Frequency of servicing & exercising valves & hydrants	Is there a regular program of servicing and exercising? Is it adequate?	
Frequency of flushing mains	Is there a regular program of main flushing? Is it adequate?	
Water main upgrading program	Is there a water main upgrading program? Is it adequate?	
Reservoir for finished water	If there are reservoirs, have they been assessed? Number, capacity, location, material of construction, operation.	
Reservoir monitoring	If there is a reservoir, is there a reservoir monitoring system? Is it adequate? Is there a sampling program in place? Is it adequate?	
Other distribution system characteristics.	Contact time/contact chamber. Booster stations. Rechlorination stations.	
Disinfectant residual	Minimum not maximum.	Further discussion required.
Program to monitor residuals	Does the waterworks system have a program in place to monitor residuals? - Yes/no.	Further discussion required.
Distribution Comments	Any other comments by the medical health officer, environmental health officer, or public health engineer relevant to the distribution system.	Text.

Operation and Maintenance

Item Name	Item Description	Comments
Level of classification EOCP	What is the level of classification of the water treatment and distribution systems?	EOCP: Environmental Operators' Certification Program.
Level of certification EOCP	What is the level of certification of the operator(s)?	EOCP: Environmental Operators' Certification Program.
Cross-connection control or backflow prevention programs	Is there a cross-connection control or backflow prevention program in place?	There are guidance documents; refer to AWWA.
Ongoing program of line flushing or regular reservoir draining	Is there an ongoing program of line flushing or regular reservoir draining? What is the frequency? Is it adequate?	
Overall maintenance plan	Is there an overall maintenance plan?	Text.
Maintenance Comment	Any other comments by the medical health officer, environmental health officer, or public health engineer relevant to the operation and maintenance.	

Compliance with Standards and Regulations

Item Name	Item Description	Comments
BC Safe Drinking Water Regulation	Does the waterworks system comply with BC Safe Drinking Water Regulation?	
Application of industry standards (AWWA)	Did construction follow industry standards?	
Guidelines exceeded	Which Guidelines for Canadian Drinking Water Quality levis were exceeded and by how much?	
Emergency response plans	Is there an emergency response plan in place? If so, which reference document was used?	There are guidance documents.
Compliance Comments	Any other comments by the medical health officer, environmental health officer, or public health engineer relevant to compliance.	Text.
Commentary		
Other comments	Any other comments by the medical health officer, environmental health officer, or public health engineer.	Text.

Appendix F
Regional Data

Water Systems Statistics, Regional Data

Item Name	East Kootenay	Kootenay Boundary	North Okanagan	Okanagan Simil	Thompson	Fraser Valley	South Fraser	Simon Fraser	Coast Garibaldi	Central Vanc. Isl	Upper Island	Cariboo	North West	Peace Liard	Northern Interior	North Shore	Vancouver/Richmond	Capital	B.C.	Target
1 Number of water systems WS1 (more than 300 connections)	14	16	10	27	11	13	7	7	11	24	16	4	16	7	13	4	3	6	209	
WS2 (15 to 300 connections)	67	101	67	69	85	102	17	3	47	110	27	54	23	9	40	10	0	42	873	
WS3 (2 to 14 connections)	144	203	67	35	145	165	43	25	109	112	89	302	96	199	168	12	0	20	1,934	
Total number of water systems	225	320	144	131	241	280	67	35	167	246	132	360	135	215	221	26	3	68	3,016	
2 Population	82,552	82,759	119,250	233,133	137,600	243,175	575,919	517,594	80,448	245,279	122,800	77,168	91,929	66,254	134,001	741,882	188,432	334,847	4,087,179	
3 Routine inspections																				
Number of systems inspected																				
WS1 (more than 300 connections)	2	8	9	2	6	2	0	4	6	2	0	4	3	3	8	0	2	2	63	
WS2 (15 to 300 connections)	3	9	40	6	33	7	7	2	19	9	6	41	2	3	5	0	0	15	207	
WS3 (2 to 14 connections)	5	13	32	6	49	24	15	14	20	8	7	144	12	74	15	1	0	6	445	
Total inspected	10	30	81	14	88	33	22	20	45	19	13	189	17	80	28	1	2	23	715	
Per cent inspected	4%	9%	56%	11%	37%	12%	33%	57%	27%	8%	10%	53%	13%	37%	13%	4%	67%	34%	24%	100%
4 Critical hazards																				
Number of hazards found	1	0	6	4	16	6	0	1	13	1	3	13	0	0	2	0	0	1	67	
Number corrected on follow-up	1	0	5	4	14	4	0	1	13	1	3	13	0	0	2	0	0	1	62	
Per cent corrected	100%	-	83%	100%	88%	67%	-	100%	100%	100%	100%	100%	-	-	100%	-	-	100%	93%	100%
5 Hazard ratings of water systems																				
Number rated as																				
Low	43	72	114	35	110	95	29	21	105	62	36	284	88	158	112	9	2	43	1,418	
Moderate	11	124	6	5	39	15	13	7	27	7	6	8	14	25	13	3	0	4	327	
High	3	58	6	1	10	8	8	5	21	2	4	10	3	2	6	0	0	3	150	
Total number of systems rated	57	254	126	41	159	118	50	33	153	71	46	302	105	185	131	12	2	50	1,895	
Per cent rated as																				
Low	75%	28%	90%	85%	69%	81%	58%	64%	69%	87%	78%	94%	84%	85%	85%	75%	100%	86%	75%	80%
Moderate	19%	49%	5%	12%	25%	13%	26%	21%	18%	10%	13%	3%	13%	14%	10%	25%	0%	8%	17%	
High	5%	23%	5%	2%	6%	7%	16%	15%	14%	3%	9%	3%	3%	1%	5%	0%	0%	6%	8%	
Total number of systems rated	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	
6 Number of boil-water advisories	30	72	10	27	39	22	5	12	17	15	16	12	5	0	14	6	0	2	304	

Source: Population estimates from BC STATS, Ministry of Management Services. All other figures are from Public Health Protection, B.C. Ministry of Health Services.

Notes

1 Number of water systems as of March 31, 2000. Excludes First Nations water systems.
2 Estimated population living in the region in July 2000.
3 Number and per cent of water systems that received at least one routine inspection by an Environmental Health Officer in fiscal year 1999/2000.
4 Number of critical hazards found during routine and complaint inspections, and the number and per cent of hazards that had been corrected by the time of follow-up inspection, 1999/2000. A critical hazard is a health hazard that requires immediate attention; this includes microbiological or chemical contamination of raw water supply, contamination of finished water (in reservoir or mains), cross-connection, or use of unapproved source. If inspection programs are successful, all critical hazards will be corrected by the time of first follow-up inspection.
5 Number and per cent of water systems rated as "low", "moderate", and "high" as of March 31, 2000. The hazard rating is the estimated degree of health risk in a given water system. The rating reflects the professional judgement of a medical health officer or environmental health officer, based on subjective interpretation of inspection findings and enumeration of critical hazards. Note: Hazard ratings are determined when systems are inspected. Not all systems have been rated, and some hazard ratings may not be up to date, as not all systems receive an annual inspection.
6 Number of boil-water advisories in effect as of August 2001.

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